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SEAKEEPING TRIALS OF THE STABLE SEMI-SUBMERGED PLATFORM (SSP KAIMALINO)

**DAVID W. TAYLOR NAVAL SHIP  
RESEARCH AND DEVELOPMENT CENTER**

Bethesda, Md. 20084



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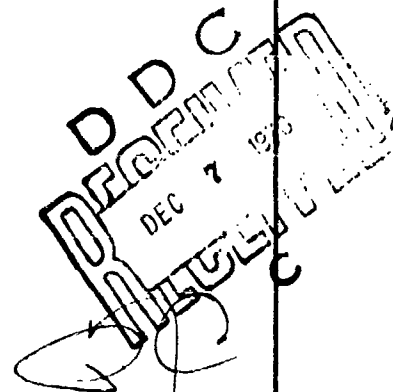
James A. Kallio

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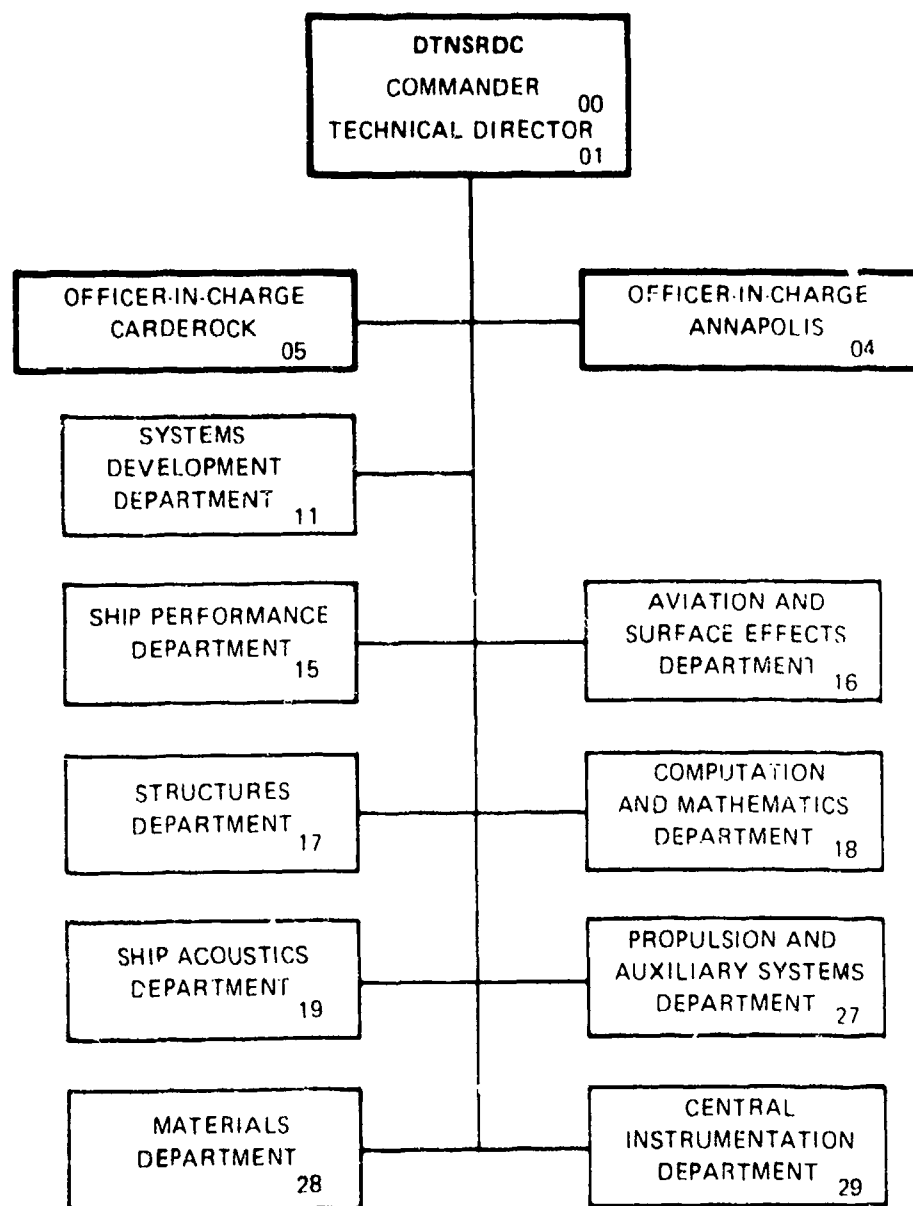
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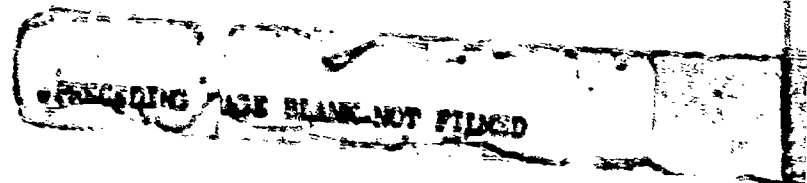
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## ABSTRACT

Full scale trials were conducted on the Stable Semi-Submerged Platform (SSP) known as the SSP Kaimalino, a Small Water Plane Twin Hull (SWATH) with an overall length of 87.8 ft (26.76m) and displacement of 193 tons (196 MTSW). Trials were conducted in a Sea State 4 at various headings and speeds. A helicopter was used to obtain motion and still photographs with an ocean-going tug running alongside for comparison purposes. Measurements were made of craft motions and accelerations as well as pressures on the cross structure due to wave impacting.

## ADMINISTRATIVE INFORMATION

These trials were conducted for the Systems Development Department, Advanced Concepts Office, David W. Taylor Naval Ship Research and Development Center (DTNSRDC), under work unit 1-1170-090.



## INTRODUCTION

Seaworthiness trials were conducted on the SSP Kaimalino as part of the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) trials program. The craft, designed by the Naval Undersea Center, (NUC) Pearl Harbor, was built at the Curtis Bay Coast Guard Shipyard. The seakeeping trials reported herein were conducted off Oahu Island, Hawaii in July 1975.

Experiments were conducted in head, bow, beam, quartering and following Sea State 4 (Significant wave height approximately 6 ft or about 2 m) at various speeds. Measurements were made of the seaway, the craft pitch, roll, heading angle, relative motion at the bow, angular rates and vertical and horizontal accelerations at various craft locations. In addition, pressures due to wave impact on the cross structure were measured at various locations along the length of the craft. A helicopter obtained motion picture and still photographs of several runs with an oceangoing tug (ATF) operating alongside to obtain a visual record for comparison of the motions of the two craft. Some of the data obtained on the full-scale craft may prove suitable for use in comparing model and full-scale experimental results.

## CRAFT DESCRIPTION

Principal dimensions and other craft characteristics are presented in Table 1, a detailed discussion of craft design and construction is given



in Reference 1<sup>4</sup>.

Although the craft waterline and displacement varied from day to day because of varied fuel loading, trial results were not significantly affected. The mean draft and craft displacement were 15.67 ft (4.78 m), 15.92 ft (4.85 m) and 193.3 tons (196.4 MTSW), 195 tons (198.1 MTSW) during the two days on which seakeeping trials were run. The vertical center of gravity (VCG) was determined by an inclining experiment in Hawaii.

Propulsion for the craft was provided by two 2230 horsepower gas turbines geared through a chain drive to controllable pitch propellers. Auxilliary diesel engine power, used for close quarter maneuvering dockside, was not used during seakeeping trials.

Control surfaces on the craft were rudders, stern foil flaps and forward canards. These surfaces were held fixed during the data collecting portion of each run.

The SSP is a twin strut SWATH design with most of the buoyancy provided by lower submerged hulls. Another feature of this particular design is the full span stern foil between the lower hulls.

Figure 1 is a sketch of the Kaimalino showing motion and acceleration transducer locations while pressure transducer locations are shown in Figure 2.

<sup>4</sup> T. Lang, T.G., J.D. Hightower and A.T. Strickland, "Design and Development of the 190 Ton Stable Semisubmerged Platform (SSP)" Journal of Engineering for Industry, November 1974

## DESCRIPTION OF MEASUREMENTS AND INSTRUMENTATION

Measurements were made of craft motions, accelerations, rates and wave impact pressures as well as of the seaway. Table 2 presents a list of these measurements and the transducer locations. Pitch and roll motions as well as surge, sway and vertical accelerations were measured by means of a stabilized platform located on the centerline just forward of Frame 24. Vertical accelerations were also measured in the pilot house (Frame 5) and on the port side of the well (Frame 35). Pitch, roll and yaw rates were measured by means of rate gyros located just to port of the stabilized platform. Relative bow motion was measured 3 feet forward of the craft nose by means of an ultrasonic displacement transducer. Pressures due to wave impacting on the bridging structure were measured by means of strain-gaged diaphragm type pressure transducers rated at 100 psi with a flat response to 1000 hz and a natural frequency of at least 10,000 hz, and thus were more than adequate to measure the impact phenomena. The seaway was measured by a free floating buoy which telemetered wave data to the craft for recording.

During the experiments the transducer signals were amplified and recorded in analog form on paper strip chart (including an oscillograph for recording wave impacting phenomena) and analog magnetic tape. The system for recording impacts had a flat response to 1500 hz which was more than adequate for the phenomena.

## TRIAL PROGRAM AND PROCEDURE

The SSP trial program consisted of ten conditions; head, bow, beam, quartering and following sea headings run at about 9.5 and 17.5 knots in a Sea State 4 (significant wave height about 6 ft or 2 meters). About 30 minutes of real time data was collected for each run condition. In addition, about 5 minutes of data was collected during photographic runs in head, bow and beam seas at about 12 knots.

In conformity with the procedure for the other types of trials conducted on the SSP, the craft was ballasted at zero speed, to zero trim and heel condition each day before trials began. Draft readings were then made and recorded along with water temperature and specific gravity in order to determine craft displacement. Table 3 indicates craft condition for the two days during which seakeeping trials were conducted.

Prior to beginning the trials each day, the wave height buoy was deployed by the chase boat in a position which was intended to be in the center of the trials area. At all times during data collection the relative positions of buoy and craft were under the surveillance of a deck observer. All trials were run in an area where the water depth was at least 600 ft (183 m).

In preparation for each particular run, the craft was steadied up on course at the desired speed. The craft course, set to maintain a constant heading to the predominant seaway, was determined by observations from the deck and wind direction was indicated by an on-board anemometer. Once the heading and speed were set, the data collecting portion of the run

was executed until about 30 minutes of data had been recorded. No changes to control surfaces or propulsion were made during the runs except on two occasions when the propeller began to broach the water surface and the turbines idled down automatically by signal from the turbine overspeed governor control.

### TRIAL RESULTS

The motion data obtained during these trials were analyzed in both the frequency and time domains. This analysis yields mean values, power spectra, histograms and Fourier transforms as well as statistical information about the time histories. The data presented in this report are the significant double amplitudes (average of the one-third highest peak to peak excursions) of craft motions and accelerations such as relative bow motion, pitch and roll motions. Significant vertical accelerations were measured at the bow, the stable platform location and at the port side of the well. Absolute vertical motions at these locations were calculated by double integration of the acceleration response spectra and are designated as bow displacement, heave displacement and port displacement. Significant sway and surge accelerations as well as pitch, roll and yaw rates were measured at the stable platform location. Impact pressure data, extracted manually from oscillograph records, are presented in terms of frequency of impacting and impact pressure histograms. Table 3 presents mean heading, speed, pitch and roll angle and control surface angles for the various runs.

Figures 3 and 4 present the zero speed sea spectra recorded during the first and second days of the seakeeping trials. Though the data indicates the significant wave height to be slightly larger than 5 ft (1.5 m) the seaway sample was measured in an area closer to shore than that in which trials were conducted. From visual observations the significant wave height in the operating area was closer to 6 to 7 ft (2m) and the seaway unidirectionality was very good, moreso in the Molakai channel than off of Koko Head. Note the seaway data collected during photo run 3 (Figure 3) is also presented as a function of wavelength/craft length,  $\lambda/L$ .

Figures 5 through 9 present results of experiments conducted in head seas at various speeds. For the speeds tested there is no appreciable speed effect on motions, absolute vertical motion, rates or surge and sway accelerations. The vertical accelerations increase as speed increases.

The high frequency of occurrence of impacts at gage 13 (Figure 8) may be due to the large buildup of water around midships, common around 9 knots. Though the maximum pressure recorded at gage 13 was 9.8 psi (67.6 KPa) and the pressure for most samples was 6 psi (41.4 KPa) or less (see Figure 9). The N indicated on the pressure histograms is the total number of impacts samples during the run. The relative frequency is calculated by dividing the number of samples in a particular pressure range [0 to 2 psi (13.8 KPa) for example] by the total number of samples, N, and multiplying by 100.

Figures 10 through 14 present results of experiments conducted in bow quartering seas at various speeds. Here too, there is no speed effect on motions, absolute vertical motions, rates or surge and sway acceleration. The vertical accelerations increase as speed increases up to about 16.5 knots.

The high frequency of occurrence of impacts at gage 11 (Figure 13) and the low pressure magnitudes (see Figure 14) are due to the water rising up the inside of the starboard forward strut since the seaway was from the port bow direction.

Figures 15 through 19 present results of experiments conducted in beam seas at various speeds. There is an increase in roll motion and roll rate as speed increases from 9 to 17 knots and an increase in relative bow motion as speed increases from 9 to 12 knots. Sample strip chart records (Figure 15A) indicate that pitch and roll are in phase.

Figures 18 and 19 indicate very little impacting except at gage 10. Note that in Table 3 the mean roll angle during the run in which gage 10 is on the forward starboard strut and the seaway was from the port beam.

Figures 20 through 24 present results of experiments conducted in stern quartering seas at various speeds. There is an increase in pitch, roll and relative bow motion as speed increases from 9 to 16 knots while the accelerations and rates remain fairly constant because at this heading, for a given wave length, the encounter frequency decreases as the craft speed increases. The encounter period for a 400 ft (122m) wave length is

## CONCLUSIONS AND RECOMMENDATIONS

The limited amount of full scale seakeeping data reported herein tends to indicate the following trends for the SSP Kaimalino operating in Sea State 4.

1. Motions in head and bow quartering seas are smaller than in stern quartering and following seas up to about 17 knots.

2. Vertical accelerations increase as speed increases in head and bow quartering seas but vary little with speed in stern quartering and following seas.

3. Frequency of wave impacting in the bow area of the bridging structure appears higher in quartering and following sea conditions due to the larger bow down pitch attitudes which occur frequently at these headings. These bow down attitudes are also responsible for the two cases of propeller ventilation. However, propeller ventilation was overcome by trimming the craft bow up by use of control surface.

4. Since very few samples of impact data were collected during this trial, it is highly recommended that conclusions concerning frequency of impacting and impact pressure magnitudes should not be drawn from this limited amount of data.

5. In order to obtain more reliable impact data, it is recommended that more wave impact data be collected, if possible, in a higher sea state.

6. It is also recommended that additional trials be run, especially at zero speed, in a seaway with sufficient energy near synchronism and over a broad enough frequency range to obtain an estimate of motion transfer

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6. It is also recommended that additional trials be run, especially at zero speed, in a seaway with sufficient energy near synchronism and over a broad enough frequency range to obtain an estimate of motion transfer



functions for the full scale craft.

7. Additional trials are also recommended to provide an insight into strategy for controlling the craft in quartering and following seas by manual or automatic control of horizontal control surface.

TABLE 1 GEOMETRIC CHARACTERISTICS OF THE SSP KAIMALINO

Overall Length	87.8 ft	26.76 m
Submerged length, nose to trailing edge of rudder (AP)	81.25 ft	24.76 m
Submerged maximum beam	49.7 ft	15.15 m
Diameter of Submerged hulls	6.5 ft	1.98 m
Displacement	193.75 LTSW	196.9 MTSW
KG, height of CG above baseline	15.39 ft	4.69 m
Longitudinal distance, AP to CG	42.46 ft	12.94 m
KB, height of center of buoyancy above baseline	6.03 ft	1.84 m

TABLE 2 - SSP KAIMALINO TRANSDUCER LOCATIONS

Measurement	Transducer	Frame	Distance Off the Centerline feet (meter)
Pitch	Mark IV Stable Table	24	on Centerline
Roll			
Heave Acceleration			
Surge Acceleration			
Sway Acceleration	Rate Gyro	24	2 (0.6) Port
Pitch Rate			
Roll Rate			
Yaw Rate	Sonic Accelerometer	5	2 (0.6) Stbd on Centerline
Relative Bow Motion			
Vert. Bow Accel.			
Port Vert. Accel.			
P-1	Pressure Gage	35	8 (2.4) Port
P-2		11-12	7 (2.1) Stbd
P-3		11-12	7 (2.1) Port
P-4		9-10	7 (2.1) Stbd
P-5		5-6	7 (2.1) Stbd
P-6		11-12	1.3 (0.4) Stbd
P-7		11-12	1.3 (0.4) Port
P-8		10-11	1.2 (0.4) Stbd
P-9		7-8	1.2 (0.4) Stbd
P-10		4-5	4 (1.2) Stbd
P-11		5-6	17.8 (5.4) Stbd
P-12		18-19	12 (3.7) Stbd
P-13		29-30	11 (3.4) Stbd
P-14		36-37	16 (4.9) Stbd
P-15		40-41	19 (5.8) Stbd
P-16		49-50	4 (1.2) Port
P-17		54-55	on Centerline
P-18		58-59	5 (1.5) Stbd
		59-60	on Centerline

TABLE 3 - SSP KAIMALINO SEAKEEPING TRIAL MATRIX

Trial Day	Trial Area	Mean Heading	Craft Speed Knots	Significant Wave Height ft (meters)	Run No.	Mean Pitch Angle Deg Bow Up = +	Mean Roll Angle Deg Port Up = +	Mean Canard Angle Deg. Trailing	Mean Flap Angle Edge Down = +
July 26, 1976	Molokai Straight	Head Sea	12.86	5.62 (1.77)	Photo 1	+0.10	+0.78	+7.40	-3.90
		Bow Q Sea	12.10	6.08 (1.85)	Photo 2	+0.28	+0.70	+7.40	-5.50
		Beam Sea	12.75	6.28 (1.91)	Photo 3	+1.25	+0.41	+7.30	-5.40
		Head Sea	9.39	5.89 (1.80)	4040	+0.16	-0.01	+7.30	+4.00
		Stern Q Sea	9.62	5.56 (1.69)	4050	+0.16	+0.54	+7.20	+3.80
		Beam Sea	9.60		4060	+0.08	-0.61	+7.10	+3.80
July 31, 1976	Koko Head	Following Sea	10.10	5.23 (1.59)	4070	-0.27	-0.10	+5.60	+5.90
		Bow Q Sea	9.69	5.62 (1.71)	4080	-0.08	-1.09	+5.60	+5.50
		Following Sea	17.41	5.62 (1.77)	4090	-0.40	-0.35	+5.60	+5.50
		Following Sea	16.34	5.55 (1.69)	4091	+1.37	+0.54	+5.60	+0.05
		Head Sea	16.41	5.58 (1.70)	4100	+0.43	+1.15	+5.60	+3.80
		Stern Q Sea	17.41	5.33 (1.62)	4110	+0.76	+0.83	+5.60	+3.70
		Stern Q Sea	16.30	5.81 (1.77)	4111	-0.57	+0.20	+5.60	+3.70
		Bow Q Sea	16.63	5.47 (1.67)	4120	+0.53	+2.27	+5.60	+3.70
		Beam Sea	16.96		4130	+0.54	+1.84	+5.60	+3.70
		Beam Sea	16.94		4140	+0.82	-0.19	+5.60	+3.80

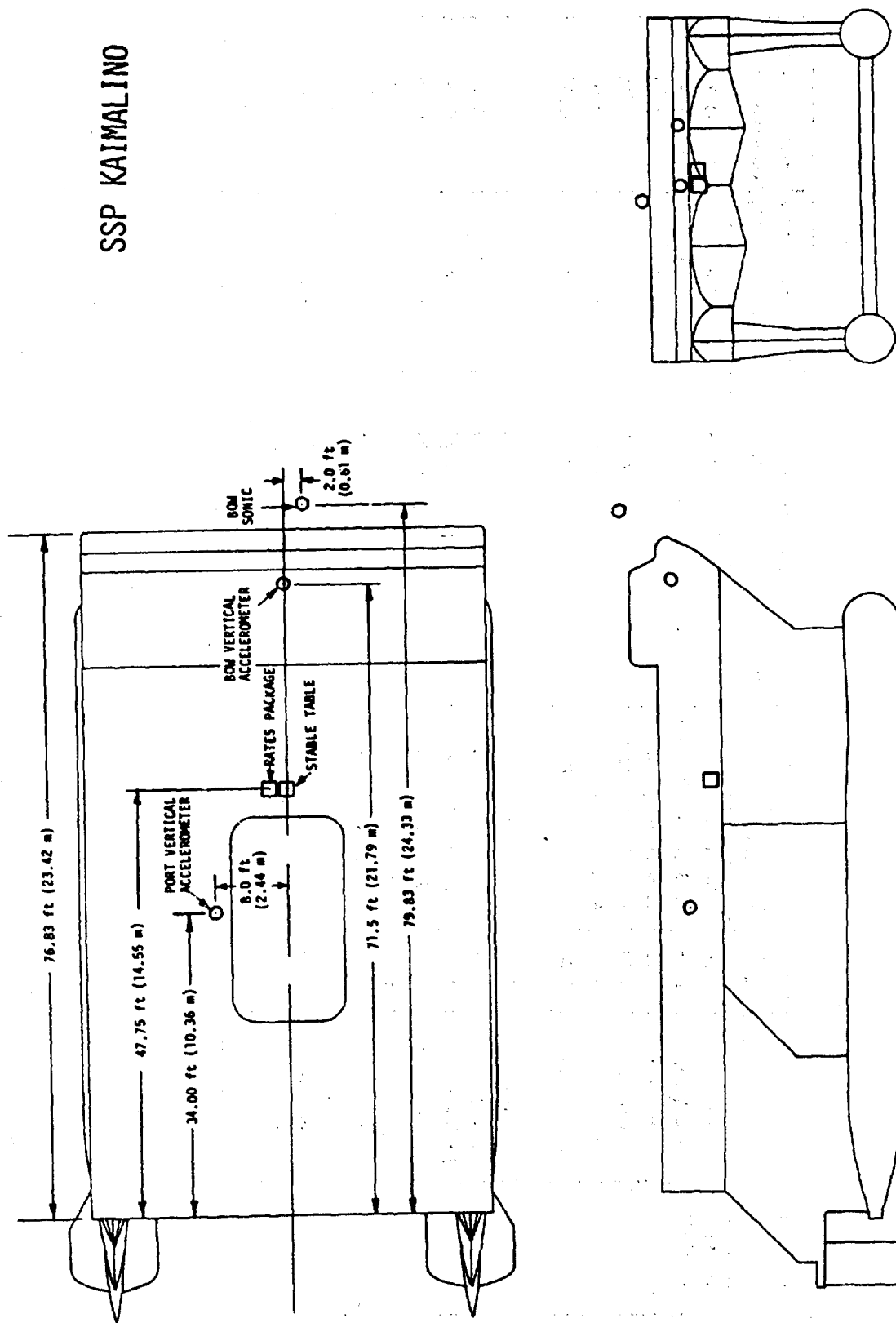


Figure 1 - SSP KAIMALINO Transducer Locations

# SSP KAIMALINO

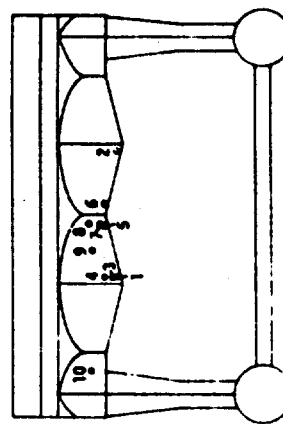
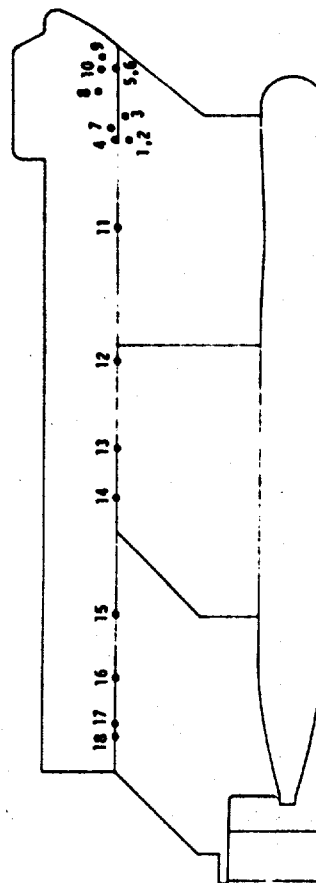
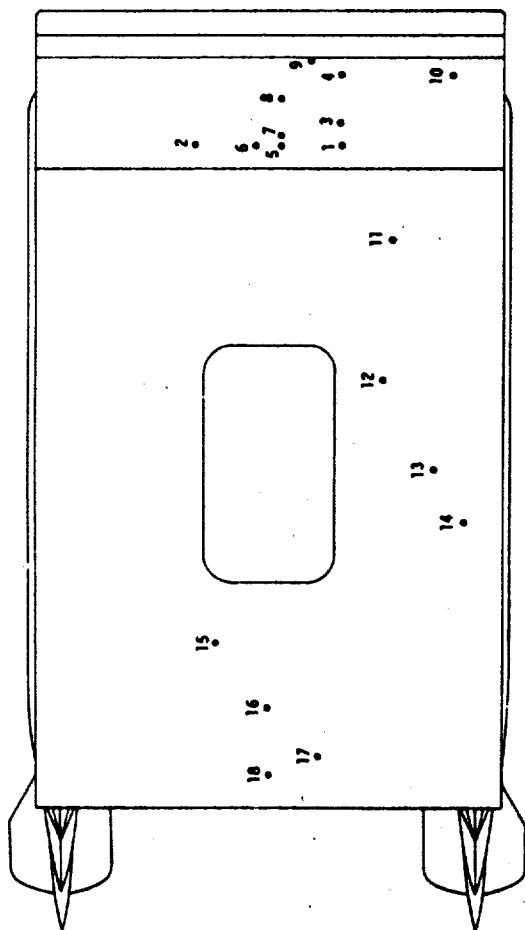


Figure 2 - SSP KAIMALINO Pressure Gage Locations

# SSP KAIMALINO

## ZERO SPEED SEA SPECTRA - MOLOKAI CHANNEL

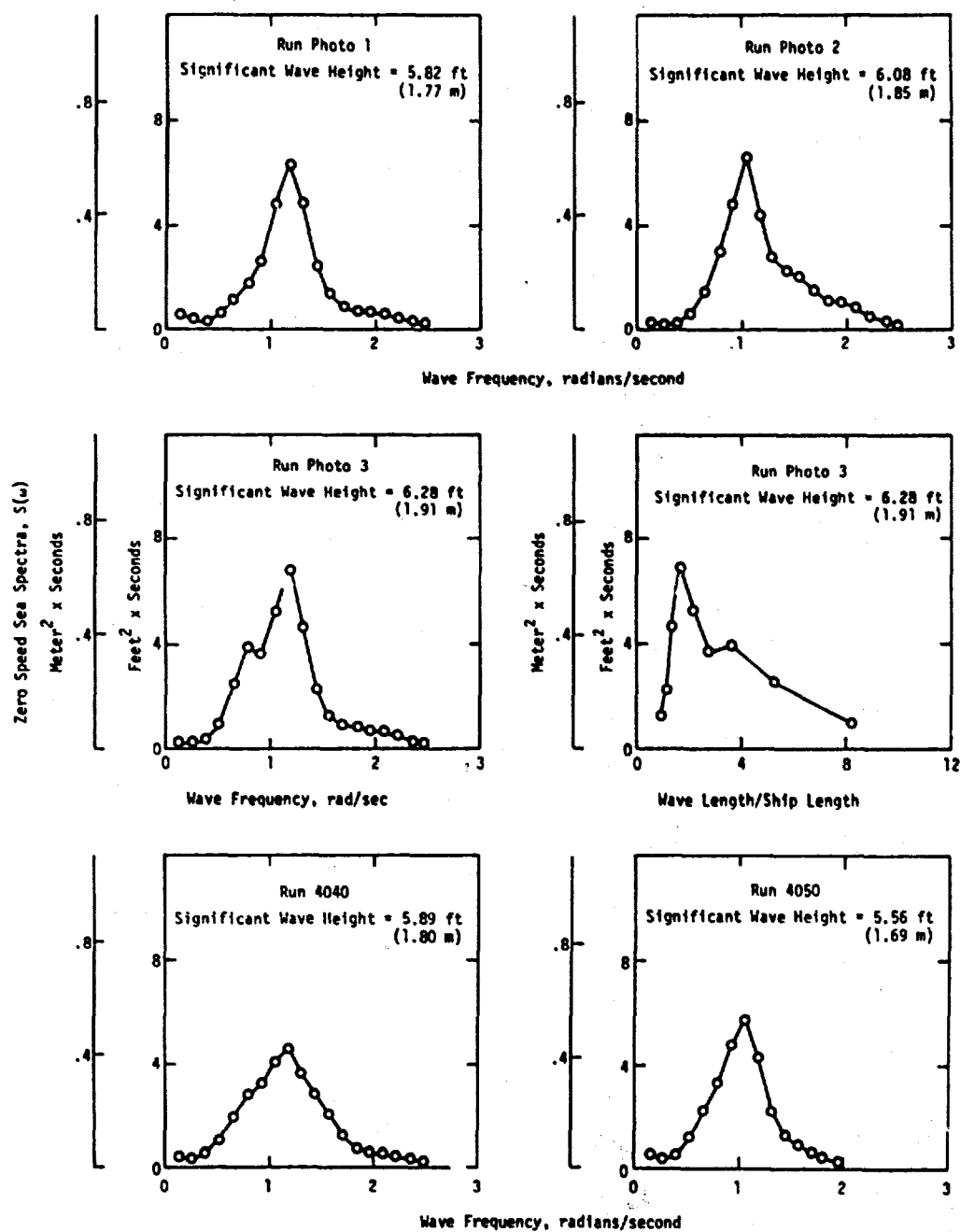


Figure 3 - ZERO Speed Sea Spectra Measured in the Molokai Channel

# SSP KAIMALINO

## ZERO SPEED SEA SPECTRA - KOKO HEAD

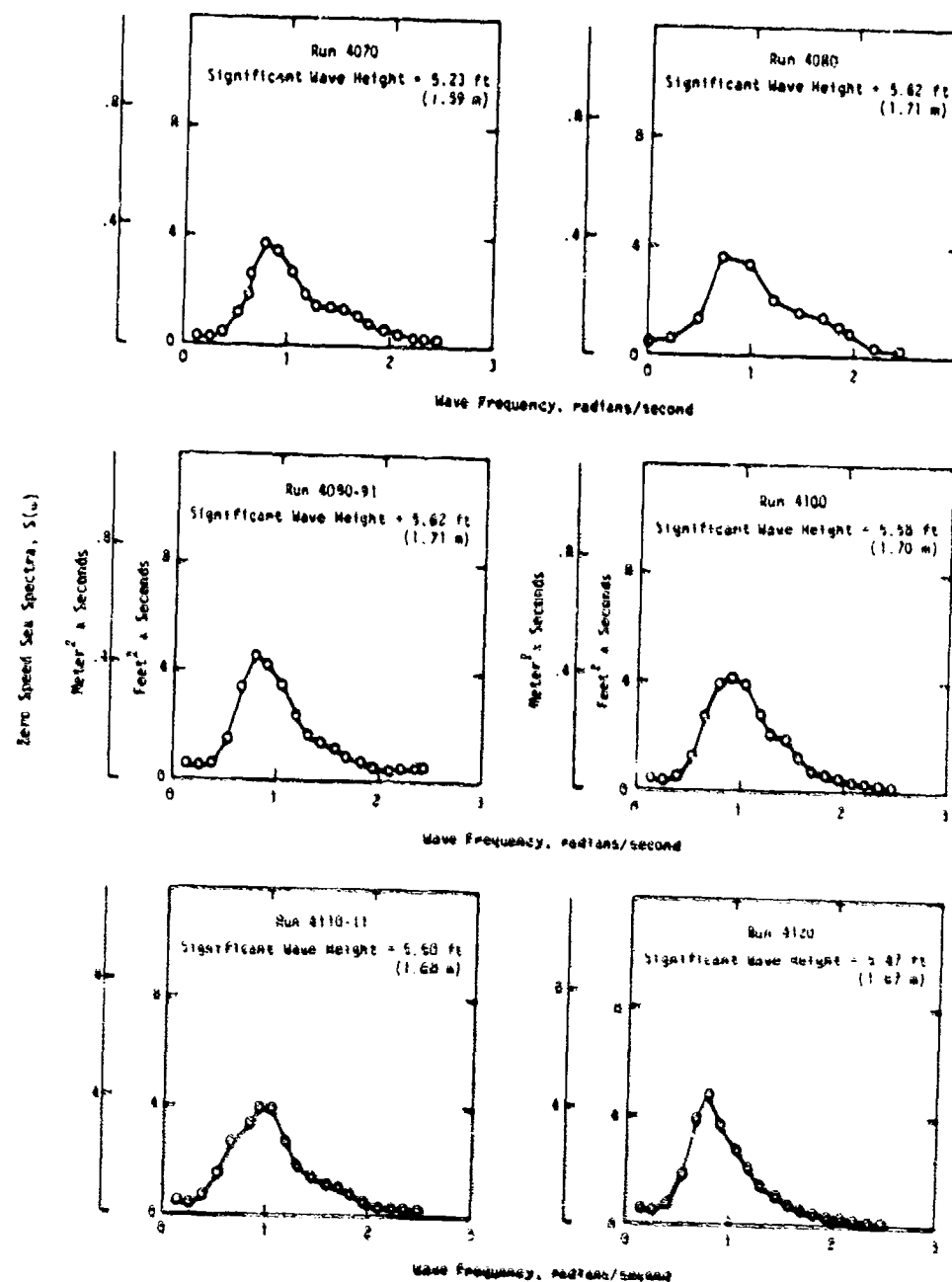


Figure 4 - ZERO Speed Sea Spectra Measured off Koko Head



# SSP KAIMALINO

HEAD SEA - 180° HEADING

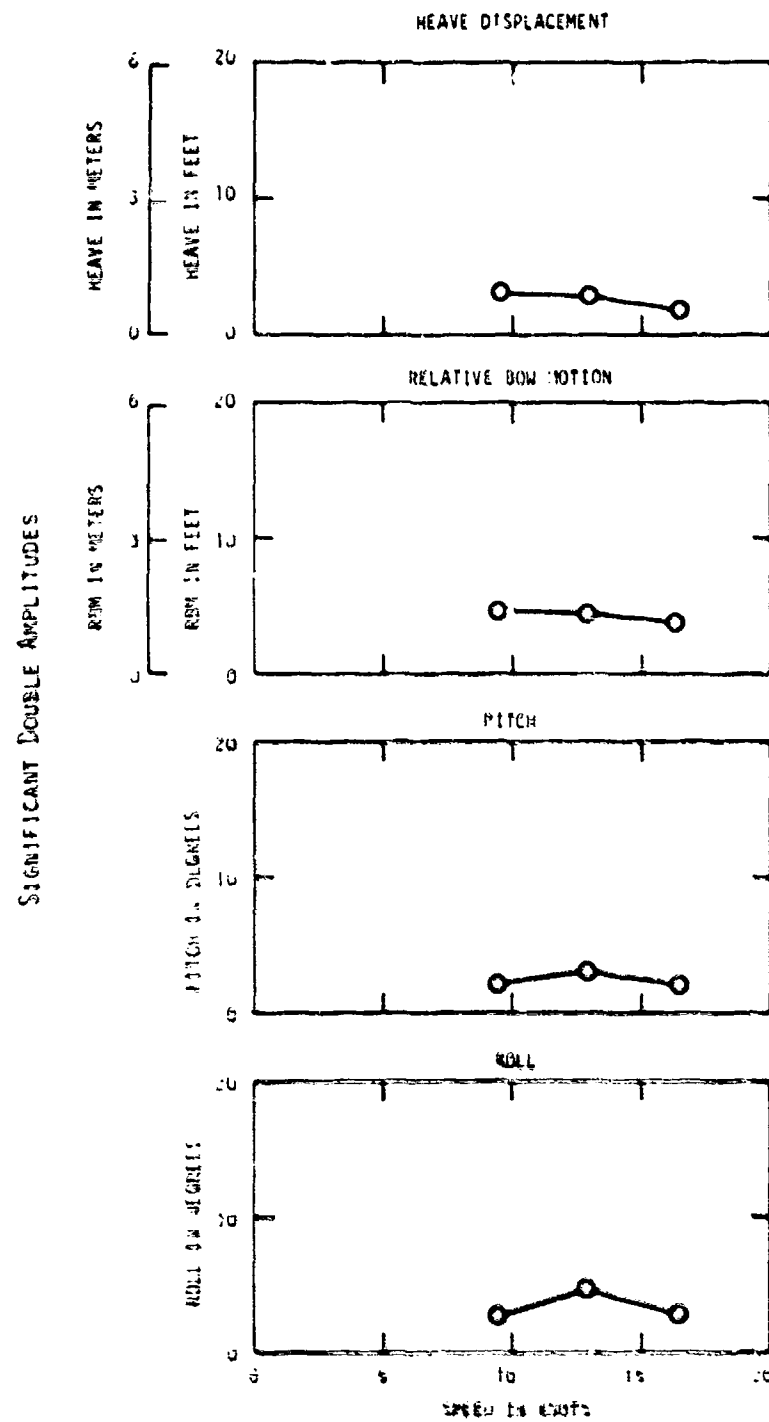


Figure 5 - SSP KAIMALINO Motions in Head Sea State 4

# SSP KAIMALINO

HEAD SEA - 130° HEADING

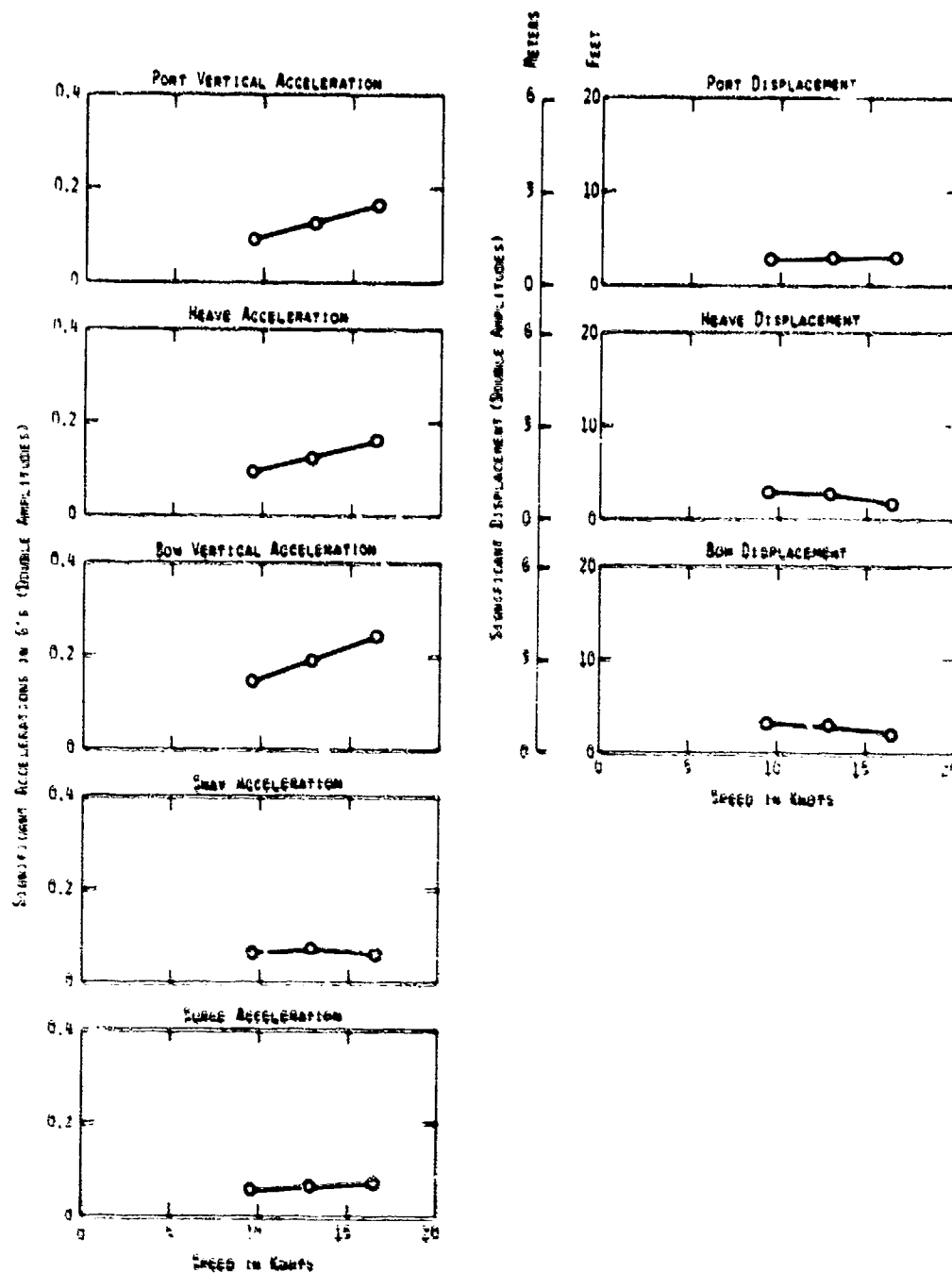


Figure 6 - SSP KAIMALINO Accelerations in Head Sea State 4

# SSP KAIMALINO

HEAD SEA = 180° Heading

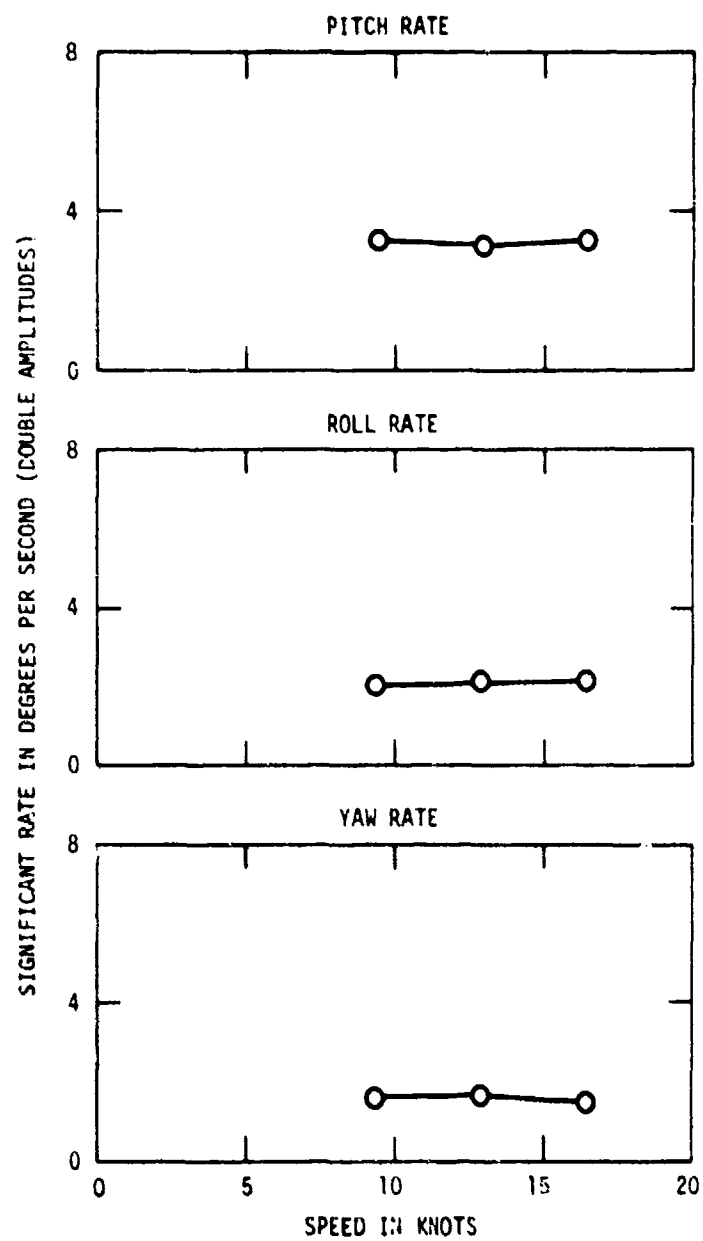


Figure 7 - SSP KAIMALINO Motion Rates in Head Sea State 4

# SSP KAIMALINO

HEAD SEA = 180° HEADING

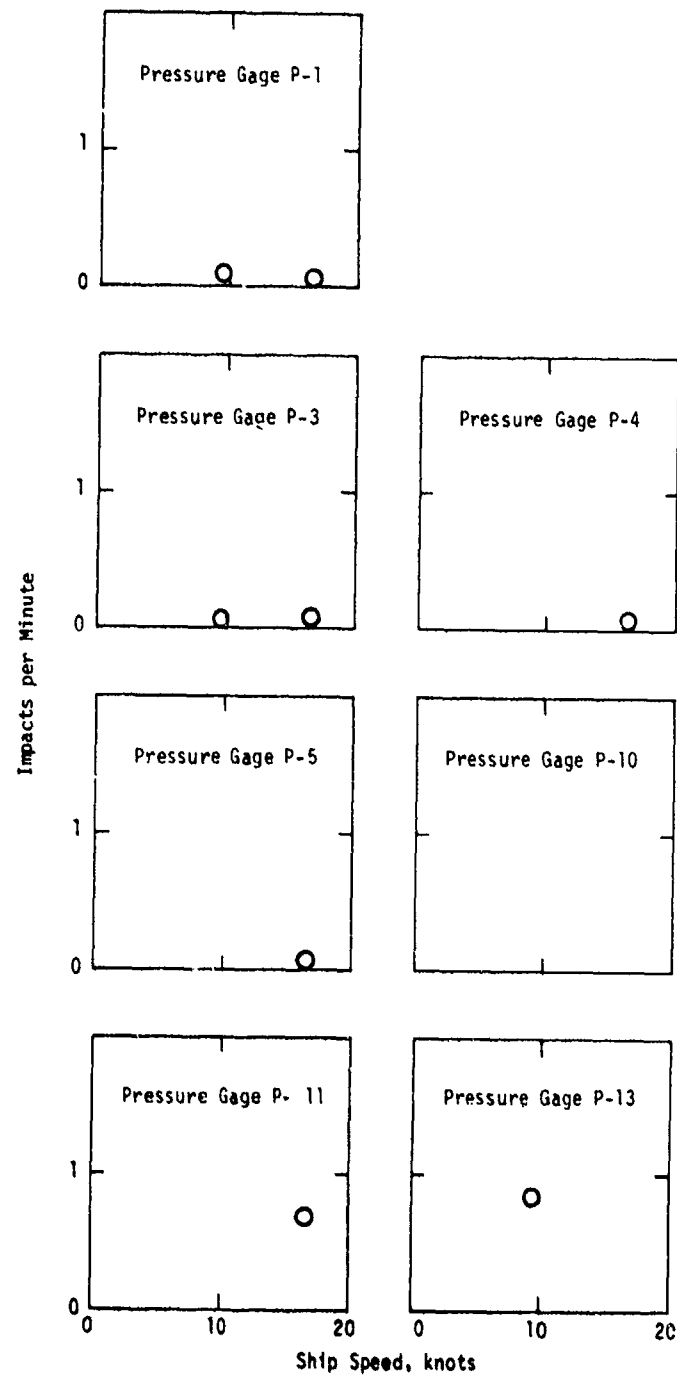


Figure 8 - SSP KAIMALINO Frequency of Impacting in Head Sea State 4

# SSP KAIMALINO

HEAD SEA = 180° HEADING

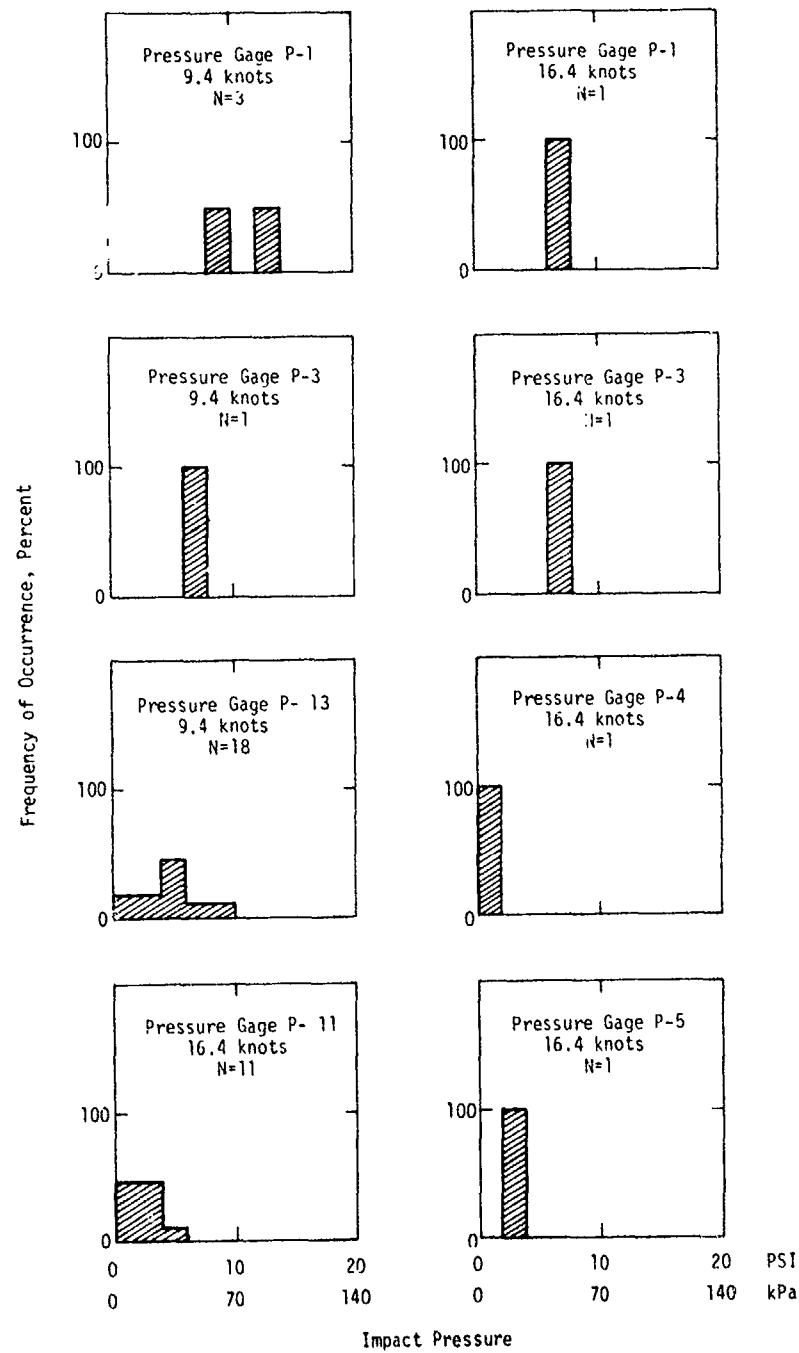


Figure 9 - SSP KAIMALINO Impact Pressure Histograms for Pressures Measured in Head Sea State 4

# SSP KAIMALINO

BOW QUARTERING SEA =  $135^{\circ}$  HEADING

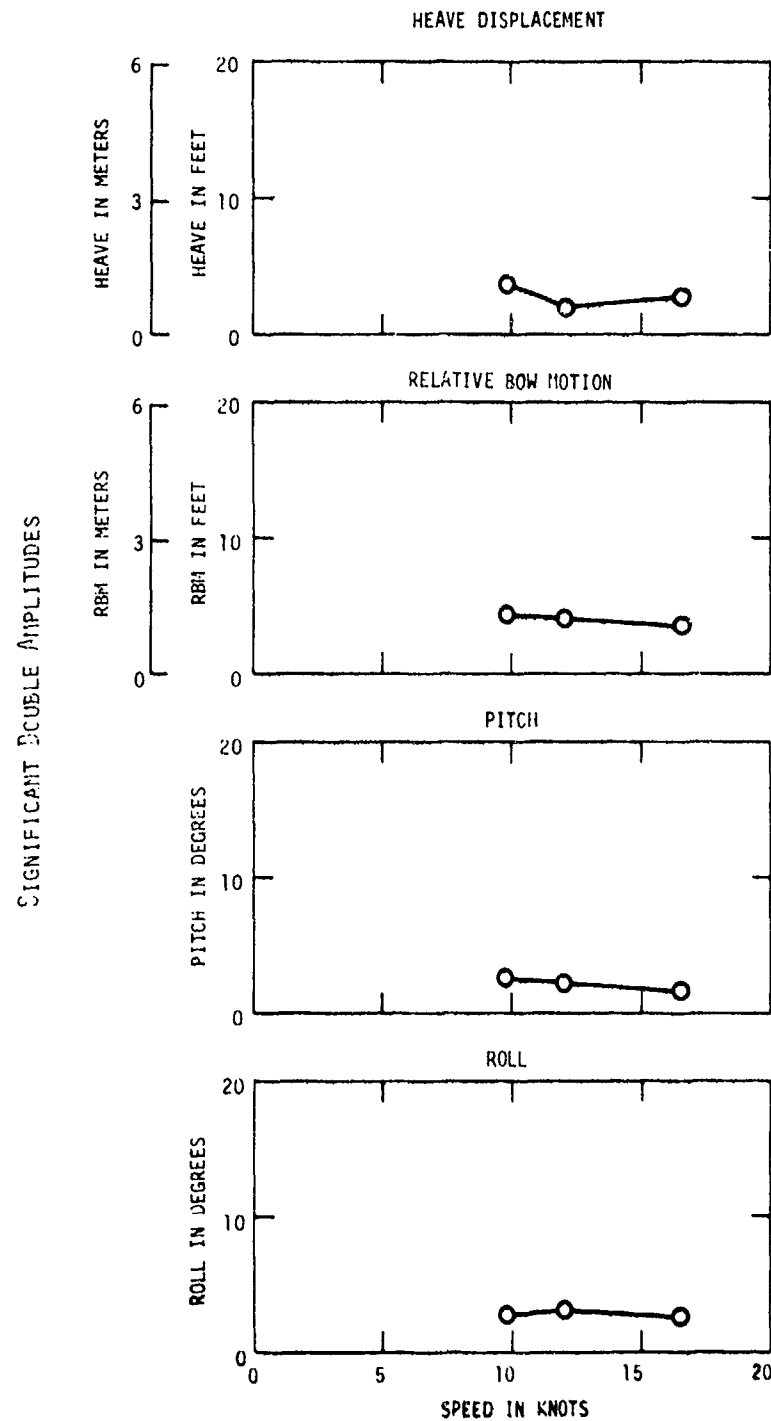


Figure 10 - SSP KAIMALINO Motions in Bow Quartering Sea State 4

# SSP KAIMALINO

BOW QUARTERING SEA = 135° HEADING

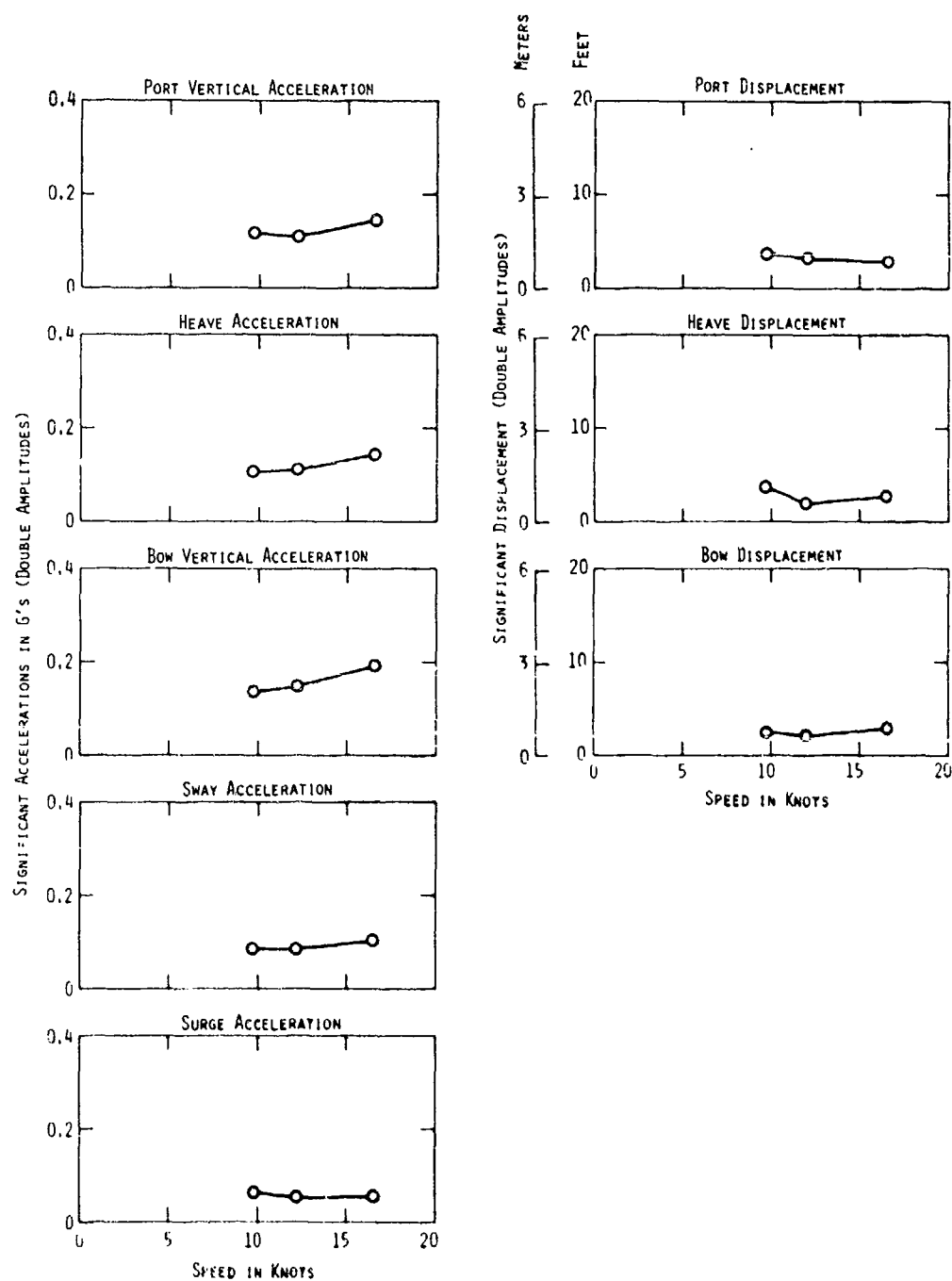


Figure 11 - SSP KAIMALINO Accelerations in Bow Quartering Sea State 4

# SSP KAIMALINO

BOW QUARTERING SEA = 135° Heading

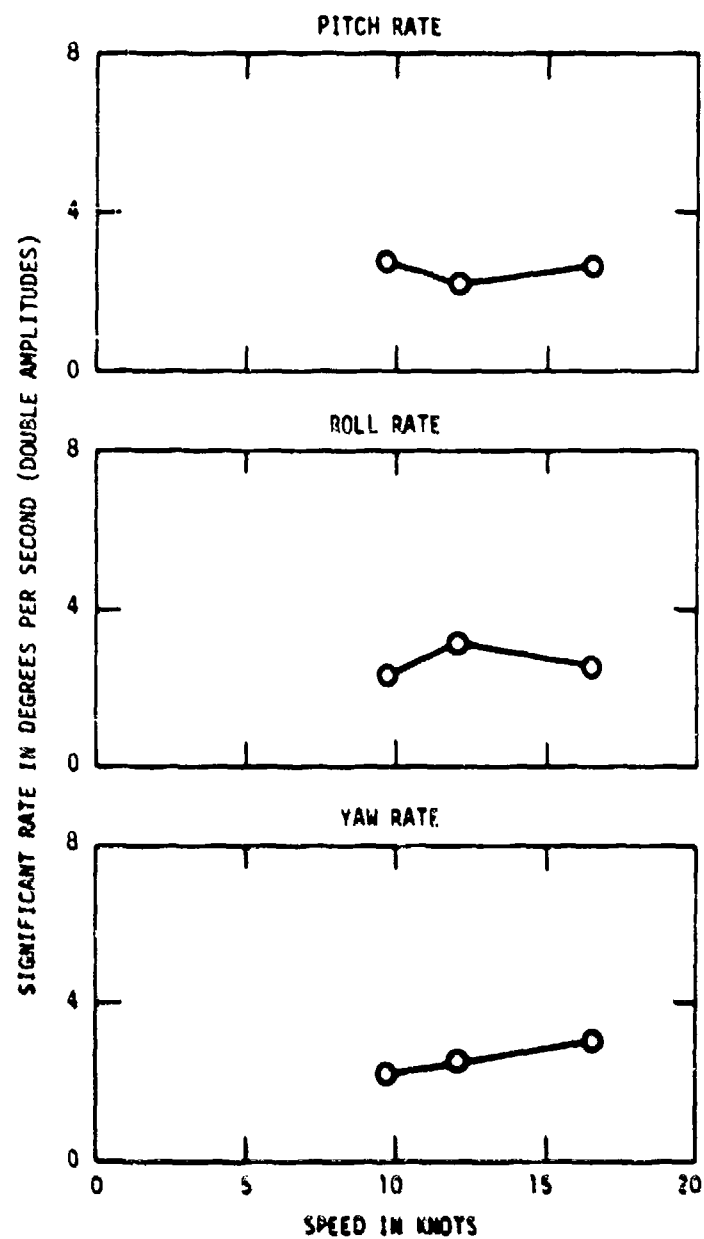


Figure 12 - SSP KAIMALINO Motion Rates in Bow Quartering Sea State 4



# SSP KAIMALINO

BOW QUARTERING SEA = 135° HEADING

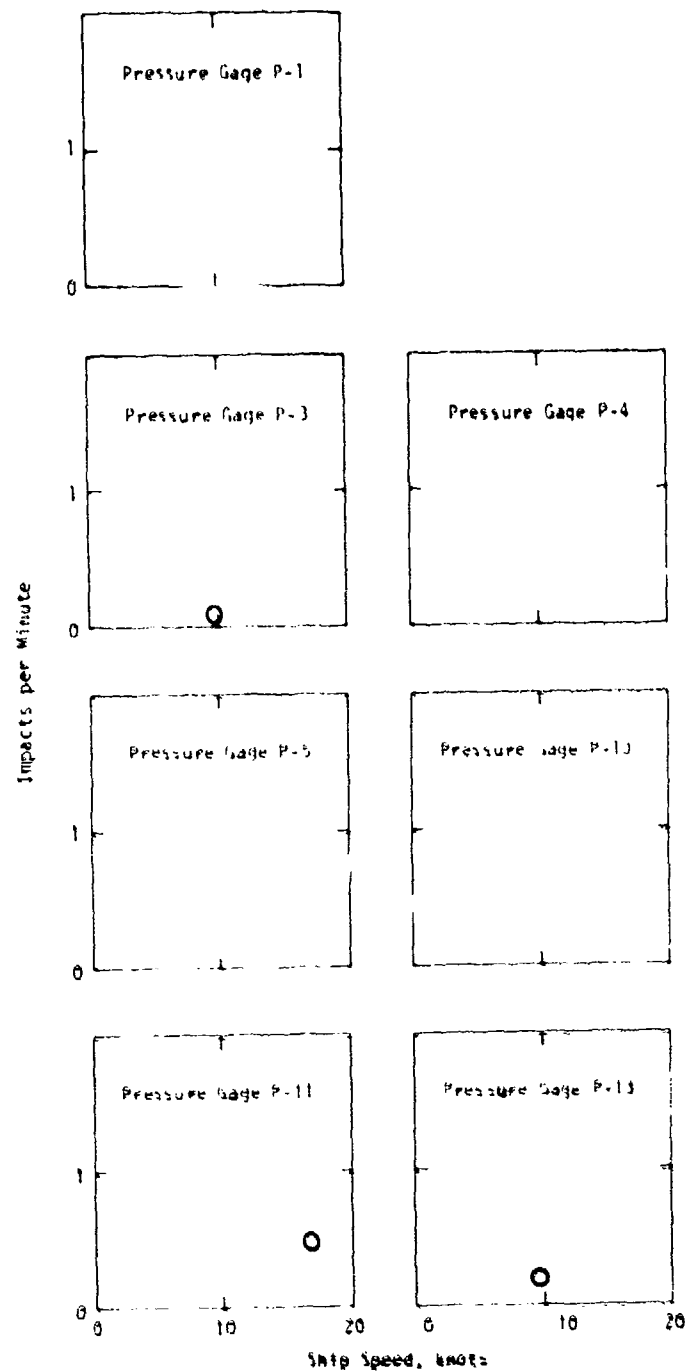


Figure 13 - SSP KAIMALINO Frequency of Impacting in Bow Quartering Sea State 4

# SSP KAIMALINO

BOW QUARTERING SEA = 135° HEADING

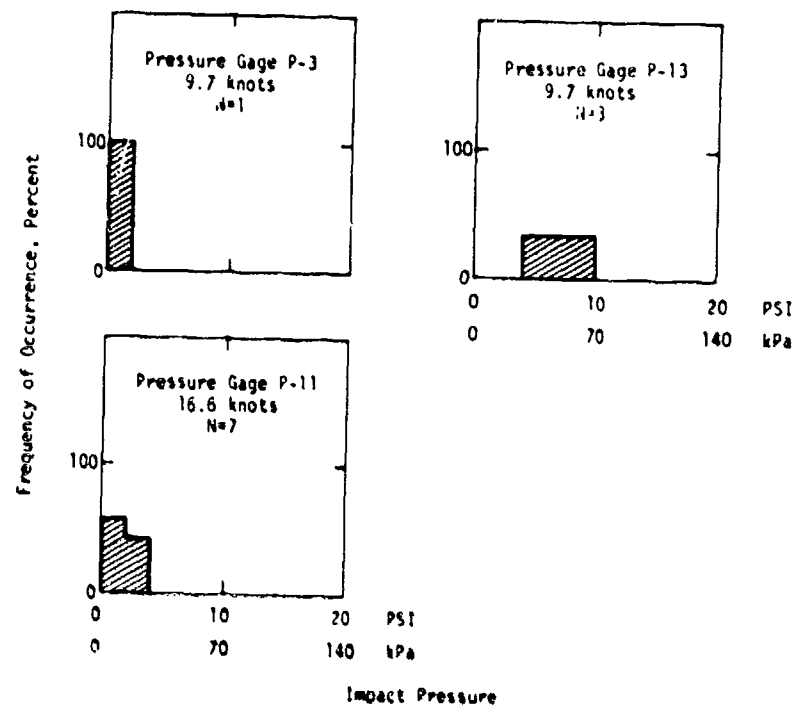


Figure 14 - SSP KAIMALINO Impact Pressure Histograms for Pressures Measured in Bow Quartering Sea State 4

# SSP KAIMALINO

BEAM SEA = 90° HEADING

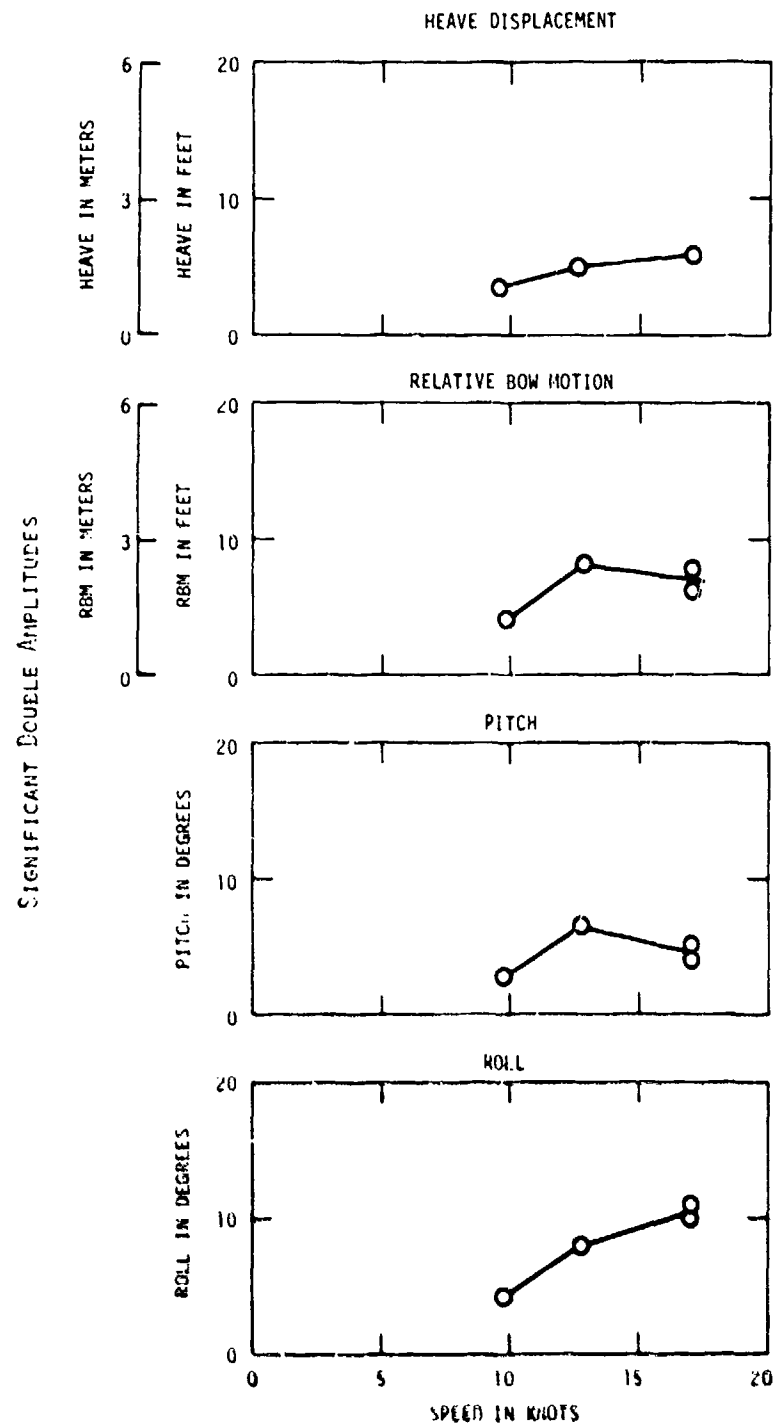


Figure 15 - SSP KAIMALINO Motions in Beam Sea State 4

# SSP KAIMALINO

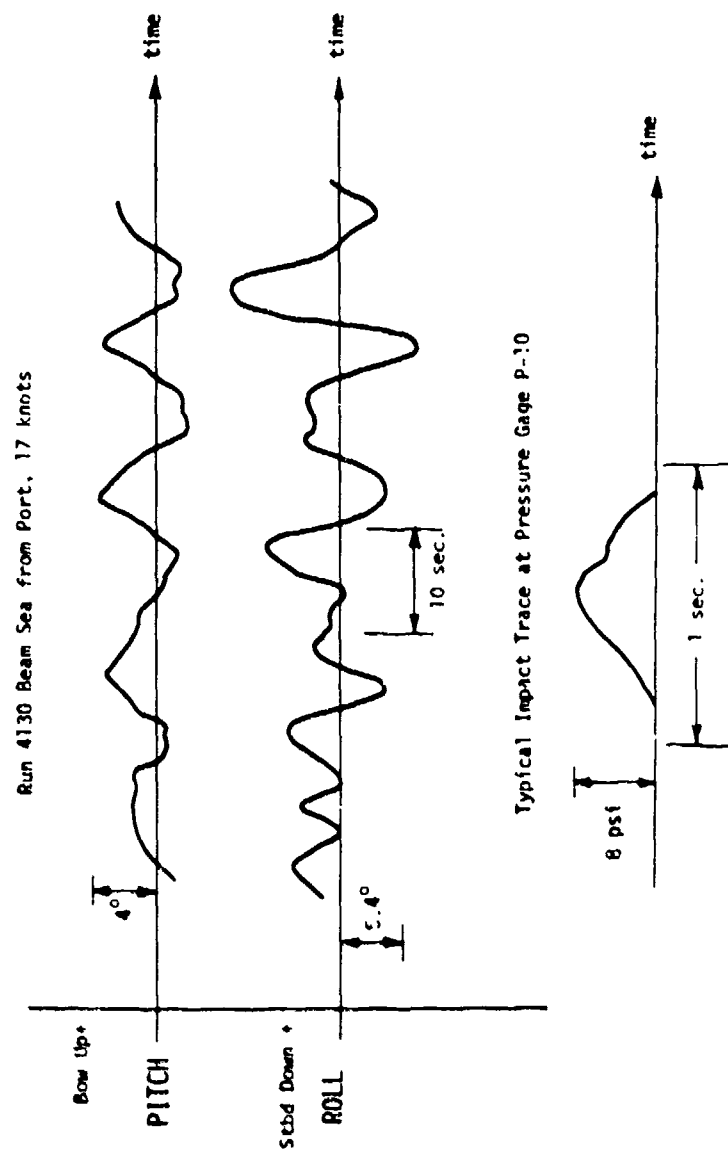


Figure 15A - Sample Strip Chart Record of Pitch, Roll and Impact Pressure in Beam Sea State 4

# SSP KAIMALINO

BEAM SEA • 90° HEADING

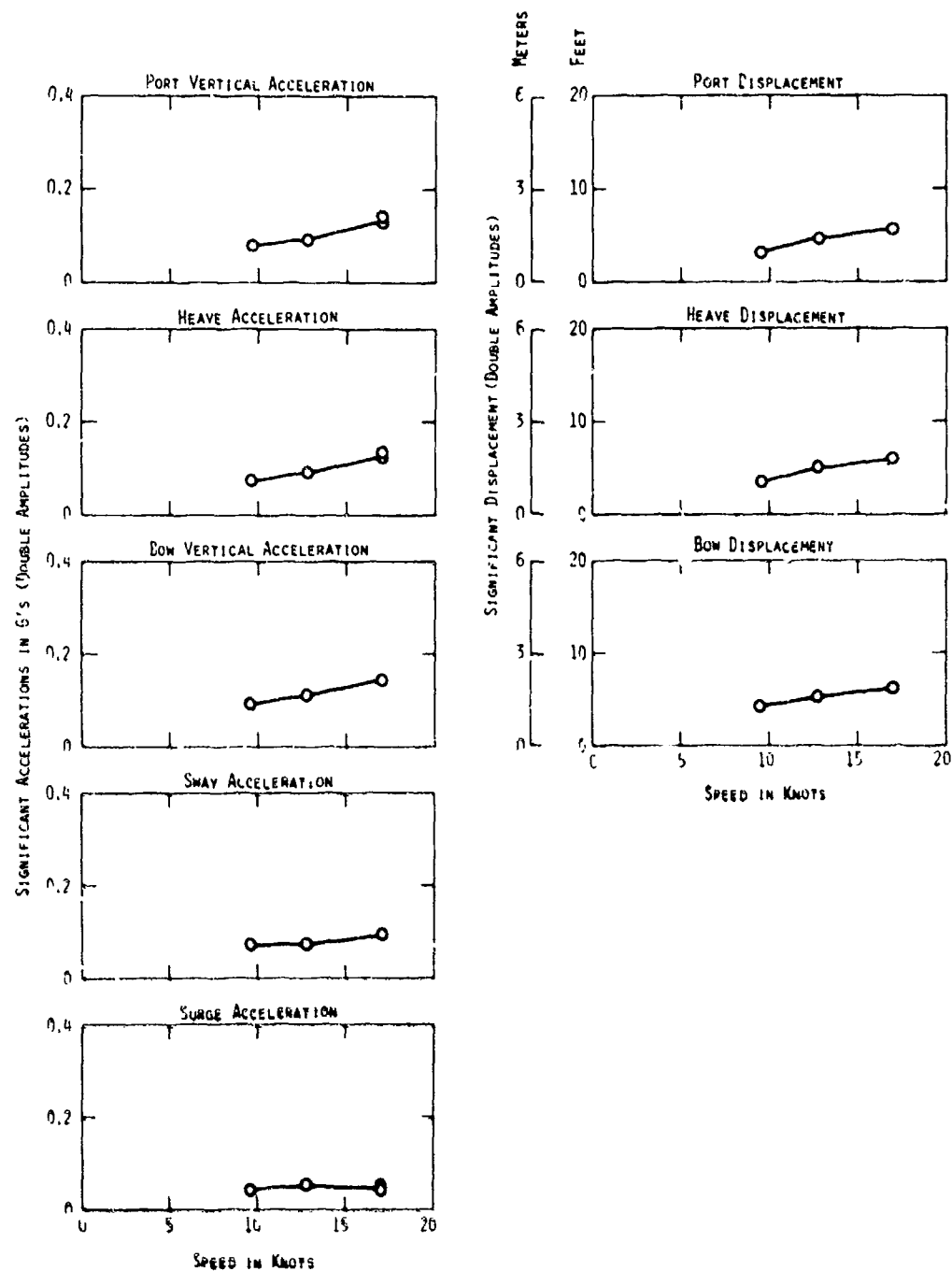


Figure 16 - SSP KAIMALINO Accelerations in Beam Sea State 4

# SSP KAIMALINO

BEAM SEA = 90° Heading

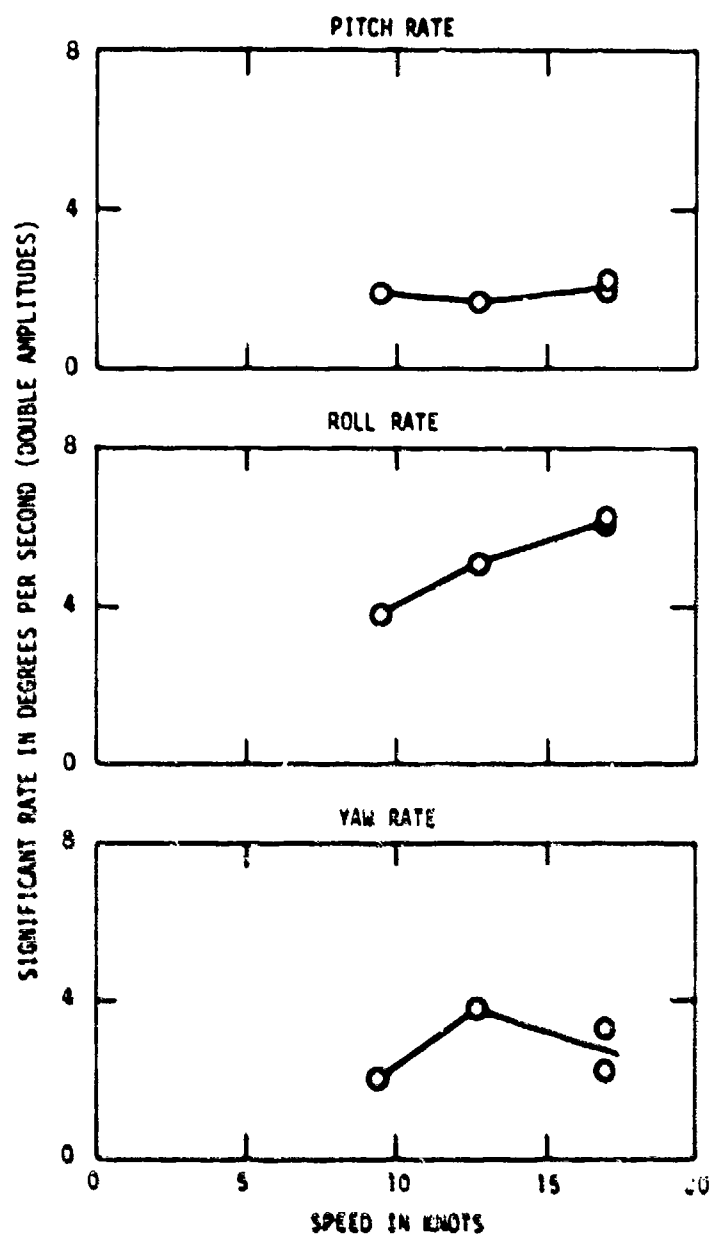


Figure 17 - SSP KAIMALINO Motion Rates in Beam Sea State 4

# SSP KAIMALINO

BEAM SEA = 90° HEADING

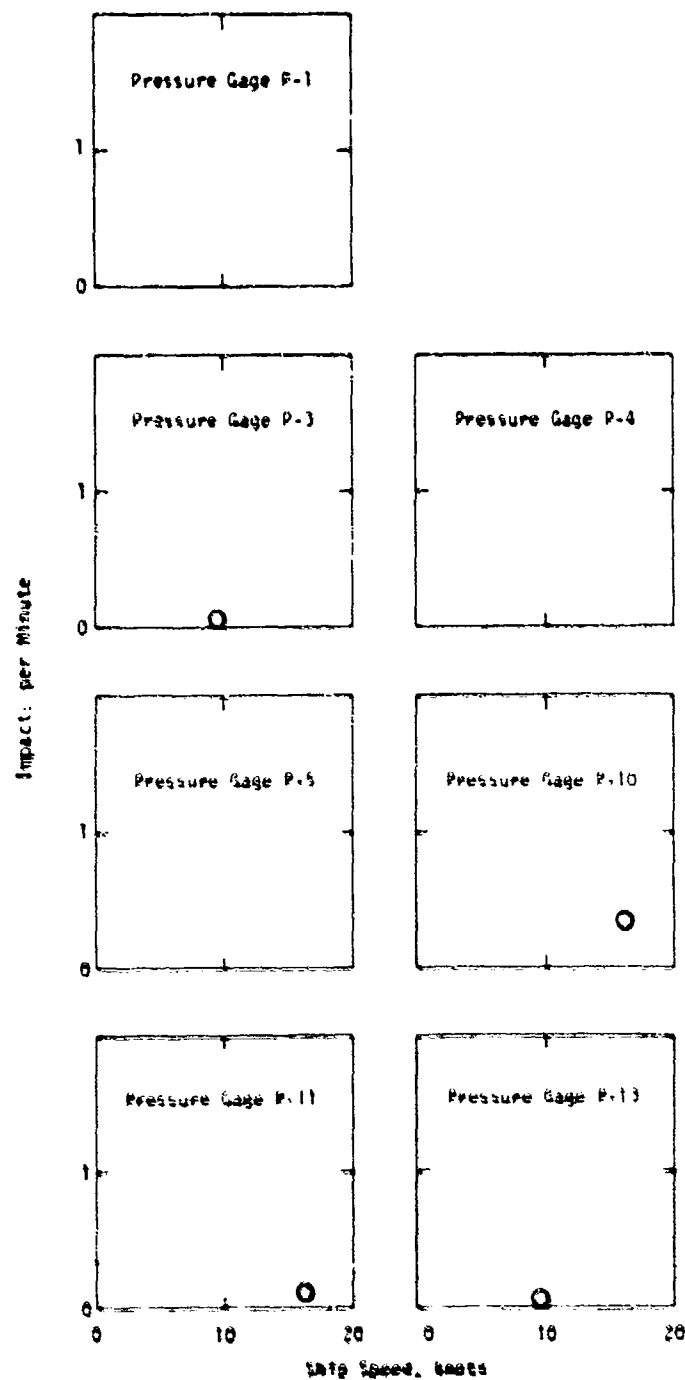


Figure 18 - SSP KAIMALINO Frequency of Impacting in Beam Sea State 4

# SSP KAIMALINO

BEAM SEA = 90° HEADING

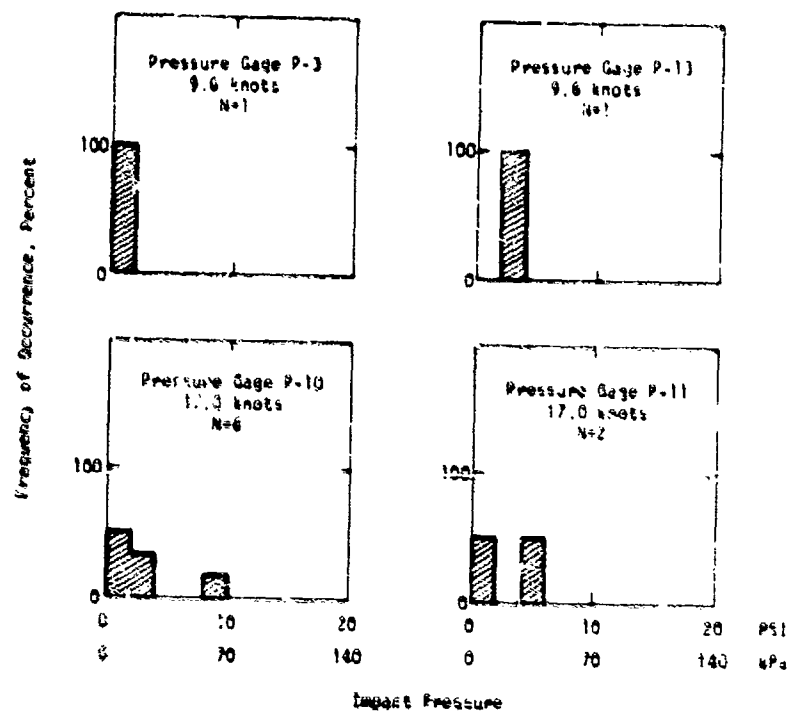


Figure 19 - SSP KAIMALINO Impact Pressure Histograms for Pressures Measured in Beam Sea State 4



# SSP KAIMALINO

STERN QUARTERING SEA = 45° HEADING

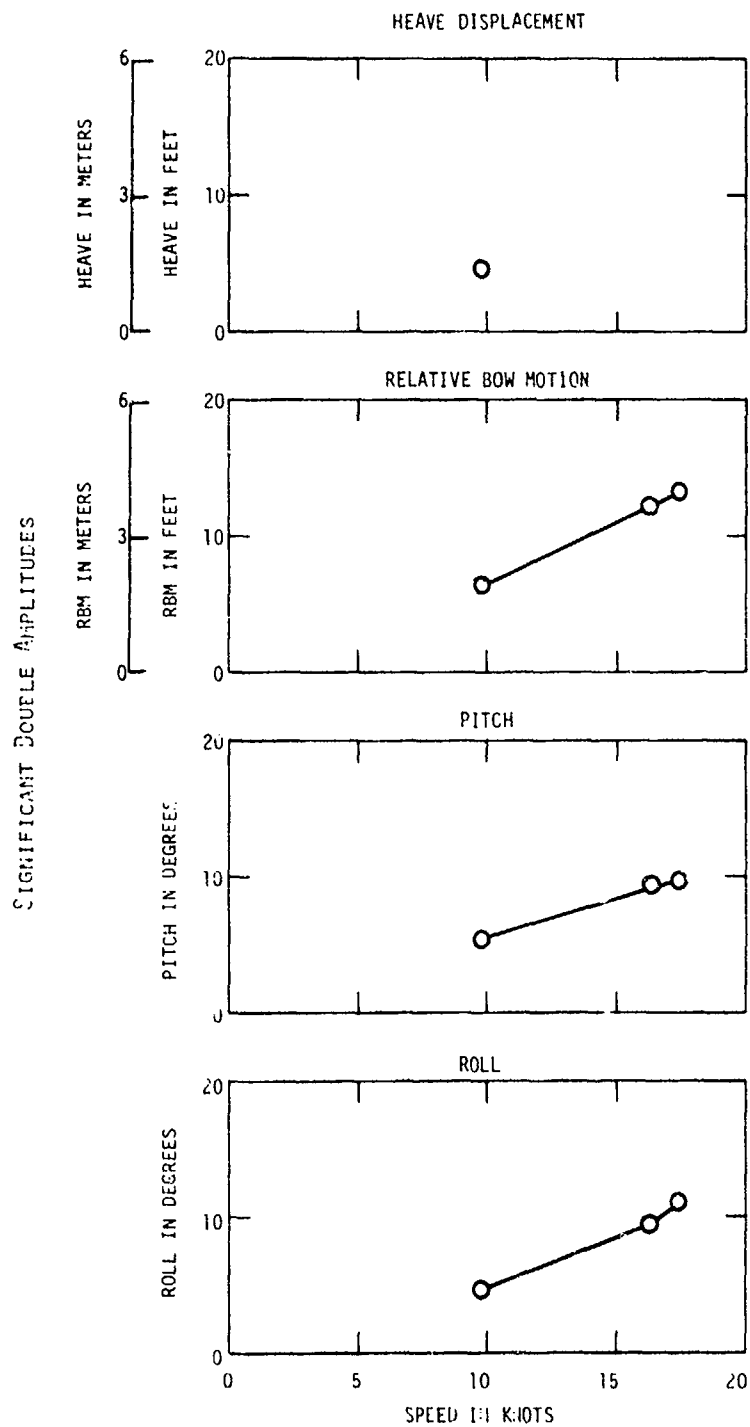


Figure 20 - SSP KAIMALINO Motions in Stern Quartering Sea State 4

# SSP KAIMALINO

Run 4110 Stern Quartering Sea from Starboard, 17.4 knots

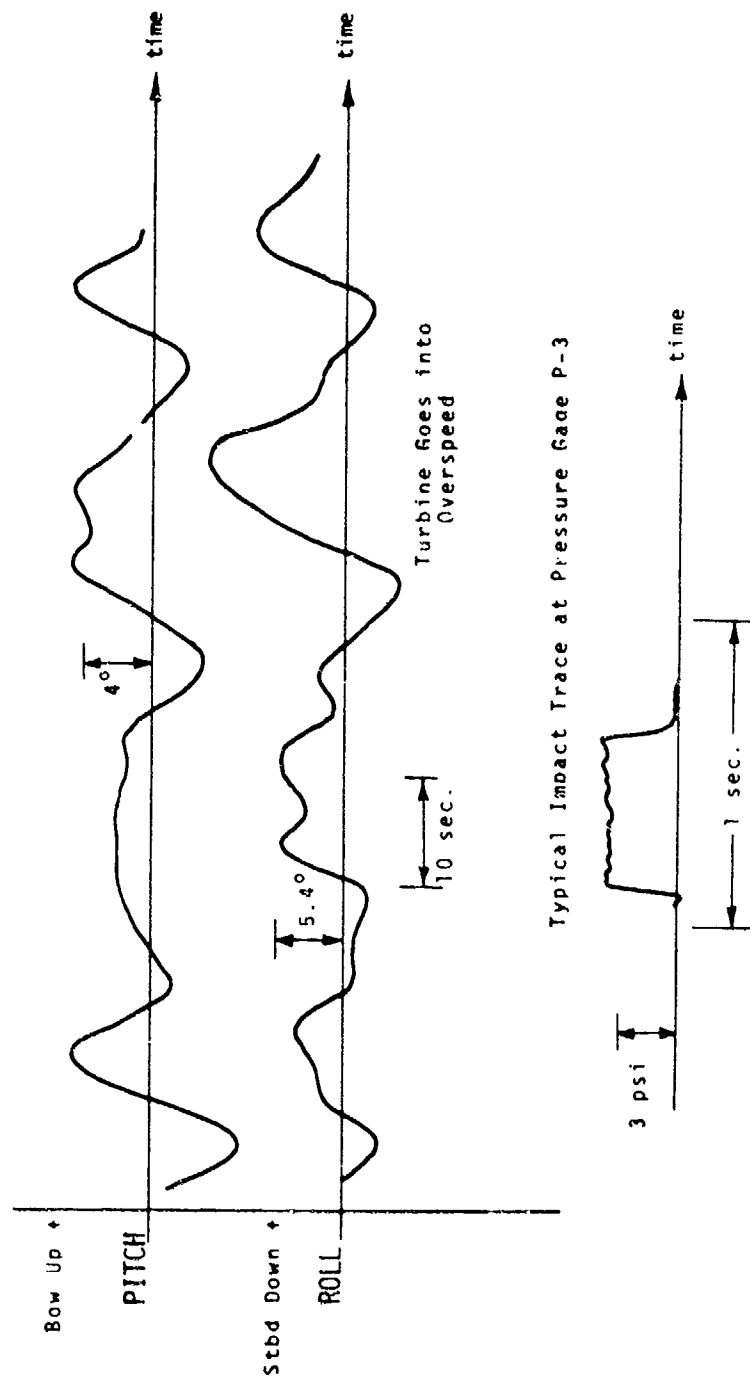


Figure 20A - Sample Strip Chart Record of Pitch, Roll and Impact Pressure in Stern Quartering Sea State 4

# SSP KAIMALINO

STERN QUARTERING SEA - 45° HEADING

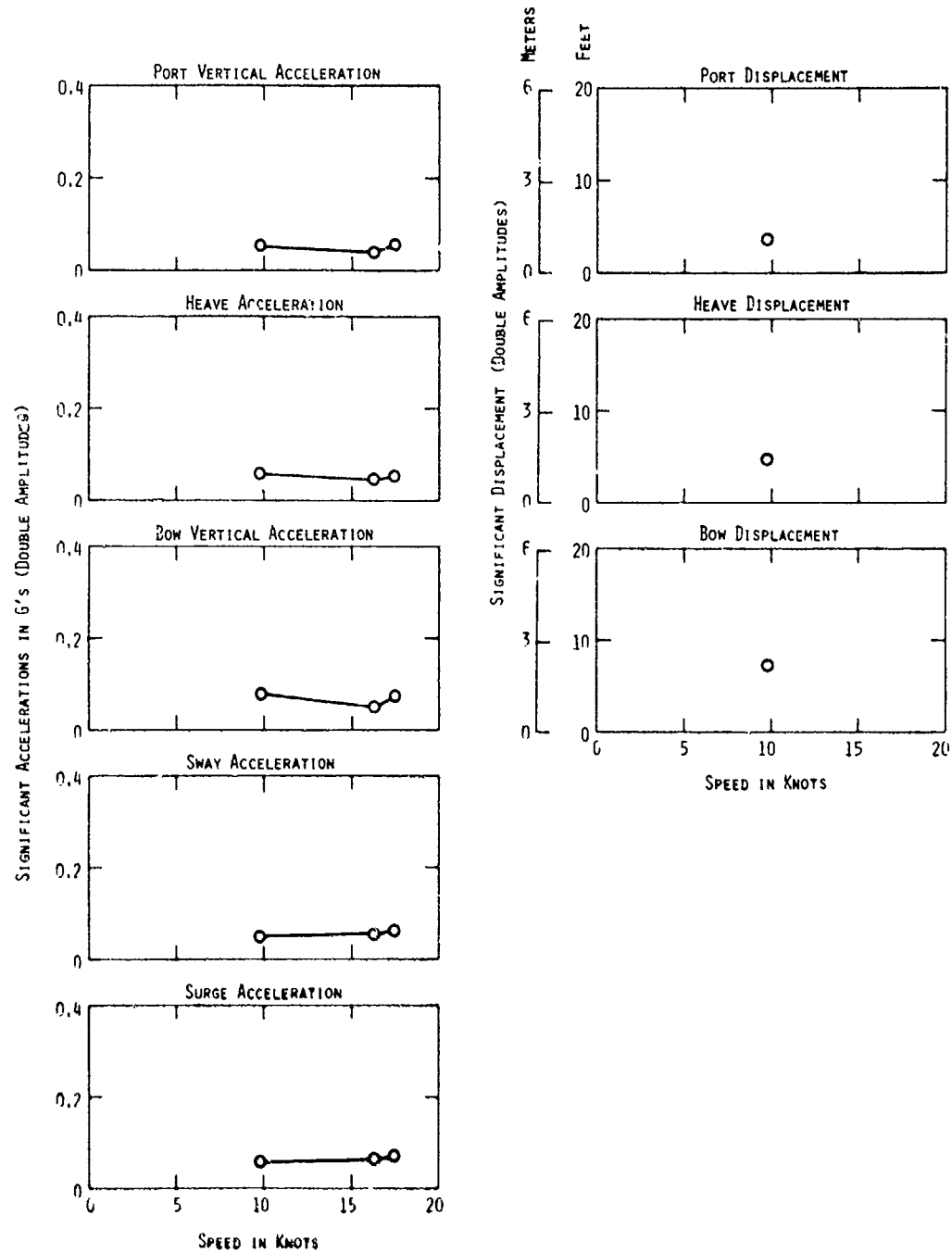


Figure 21 - SSP KAIMALINO Accelerations in Stern Quartering Sea State 4

# SSP KAIMALINO

STERN QUARTERING SEA = 45° Heading

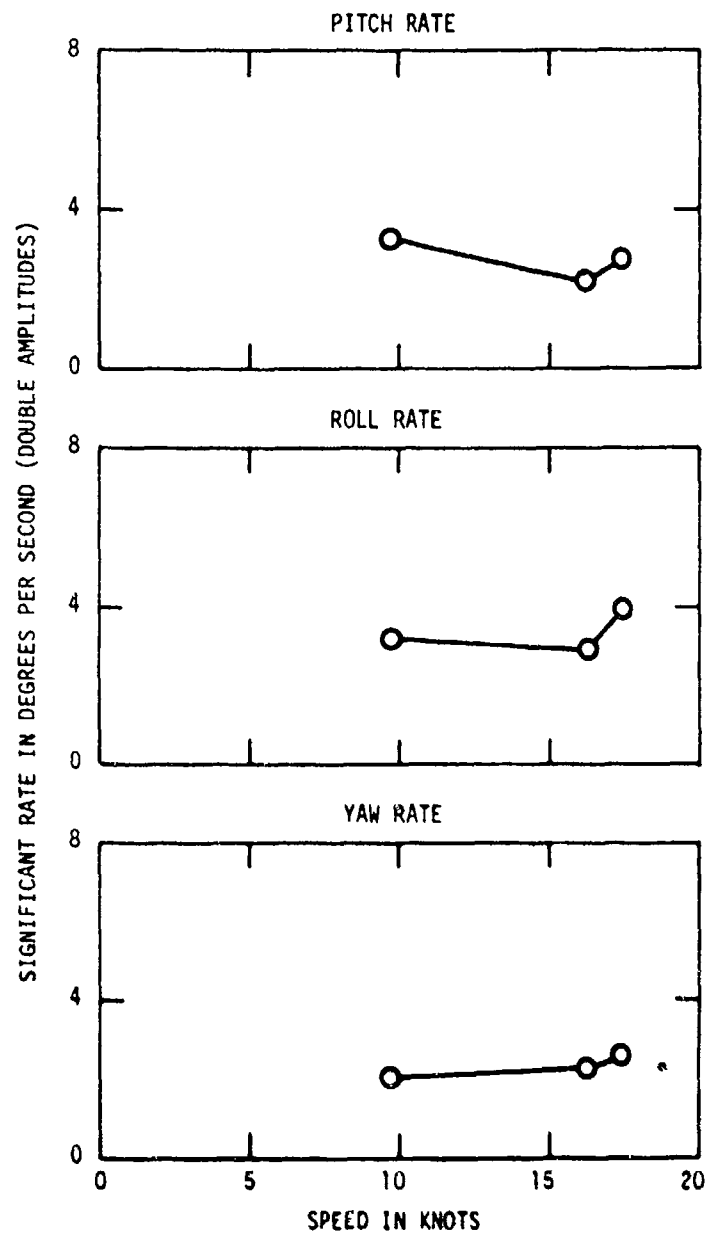


Figure 22 - SSP KAIMALINO Motion Rates in Stern Quartering Sea State 4

# SSP KAIMALINO

STERN QUARTERING SEA = 45° HEADING

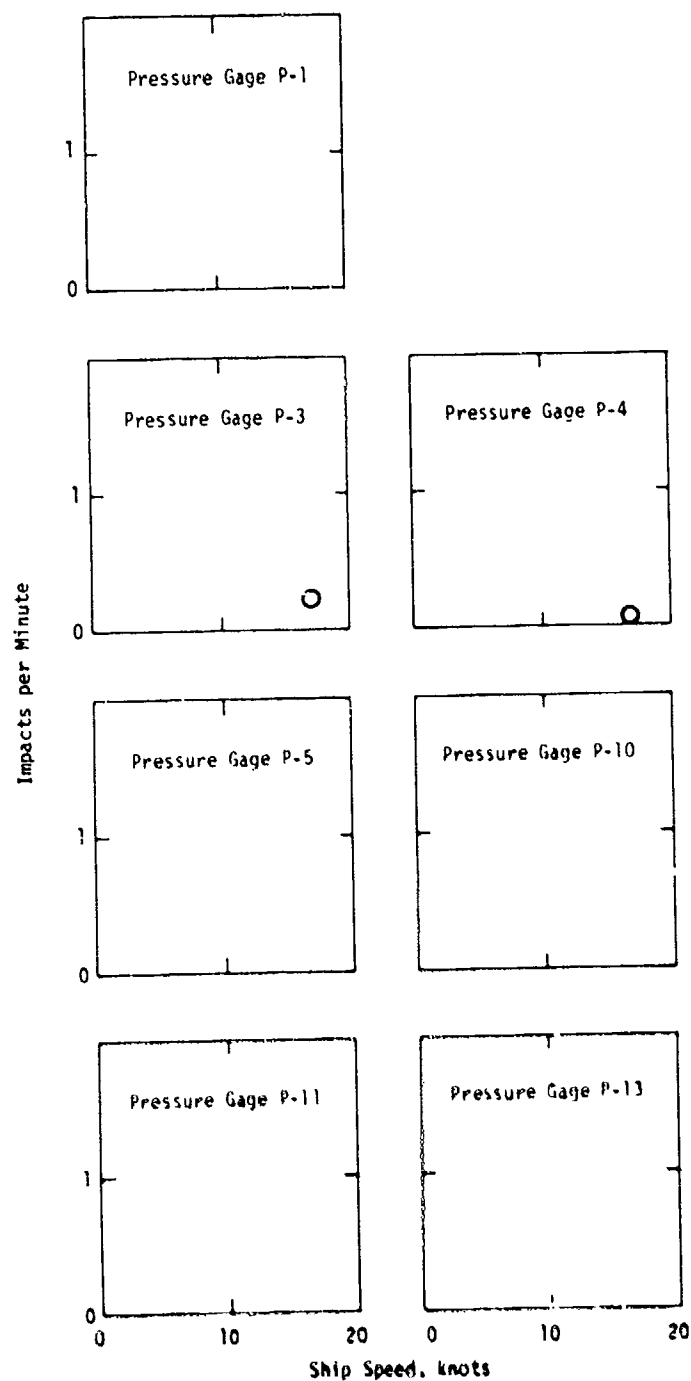


Figure 23 - SSP KAIMALINO Frequency of Impacting in Stern Quartering Sea State 4

# SSP KAIMALINO

STERN QUARTERING SEA = 45° HEADING

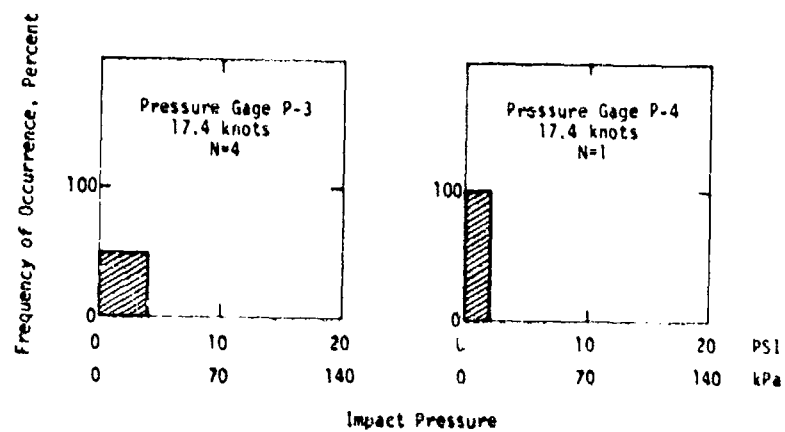


Figure 24 - SSP KAIMALINO Impact Pressure Histograms for Pressures Measured in Stern Quartering Sea State 4

# SSP KAIMALINO

FOLLOWING SEA = 0° HEADING

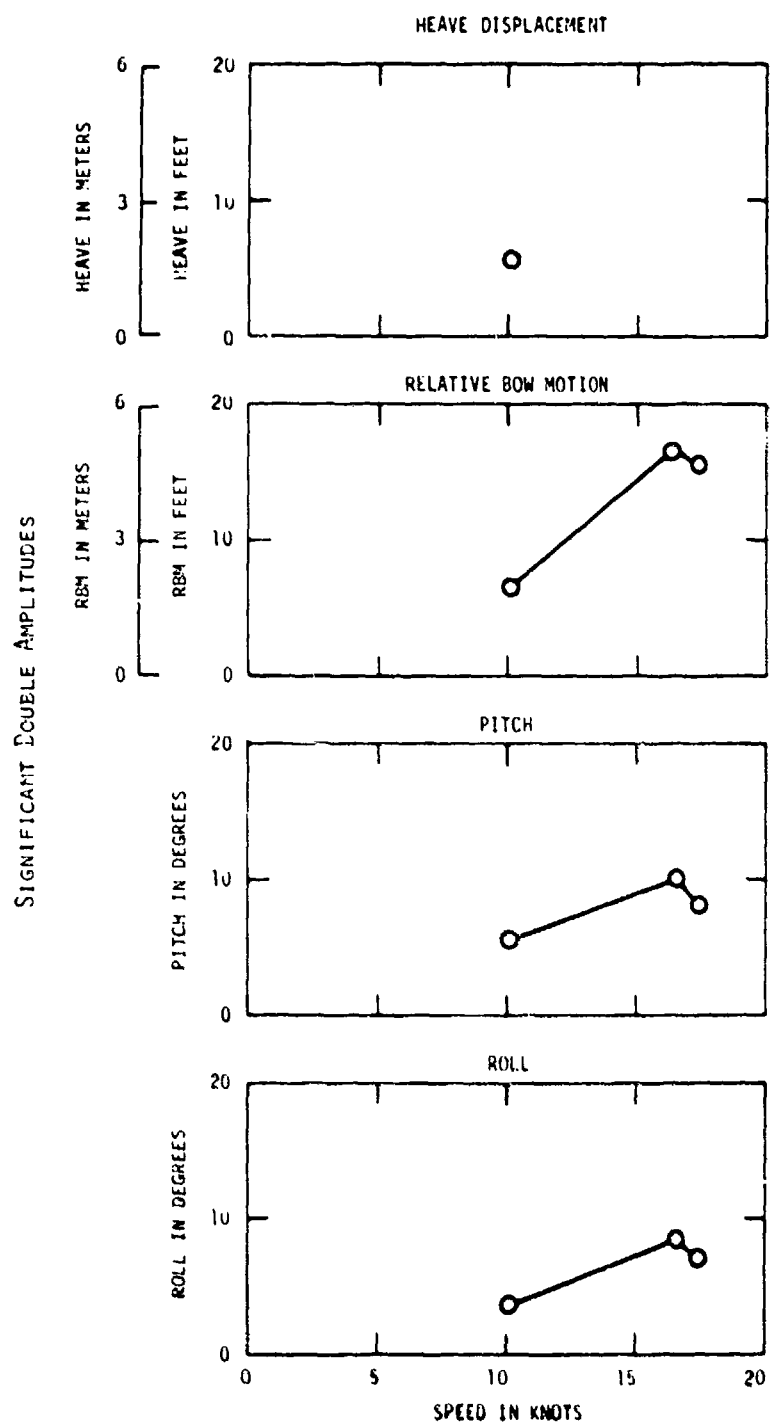


Figure 25 - SSP KAIMALINO Motions in Following Sea State 4

# SSP KAIMALINO

Run 4090 Following Sea, 17.4 knots

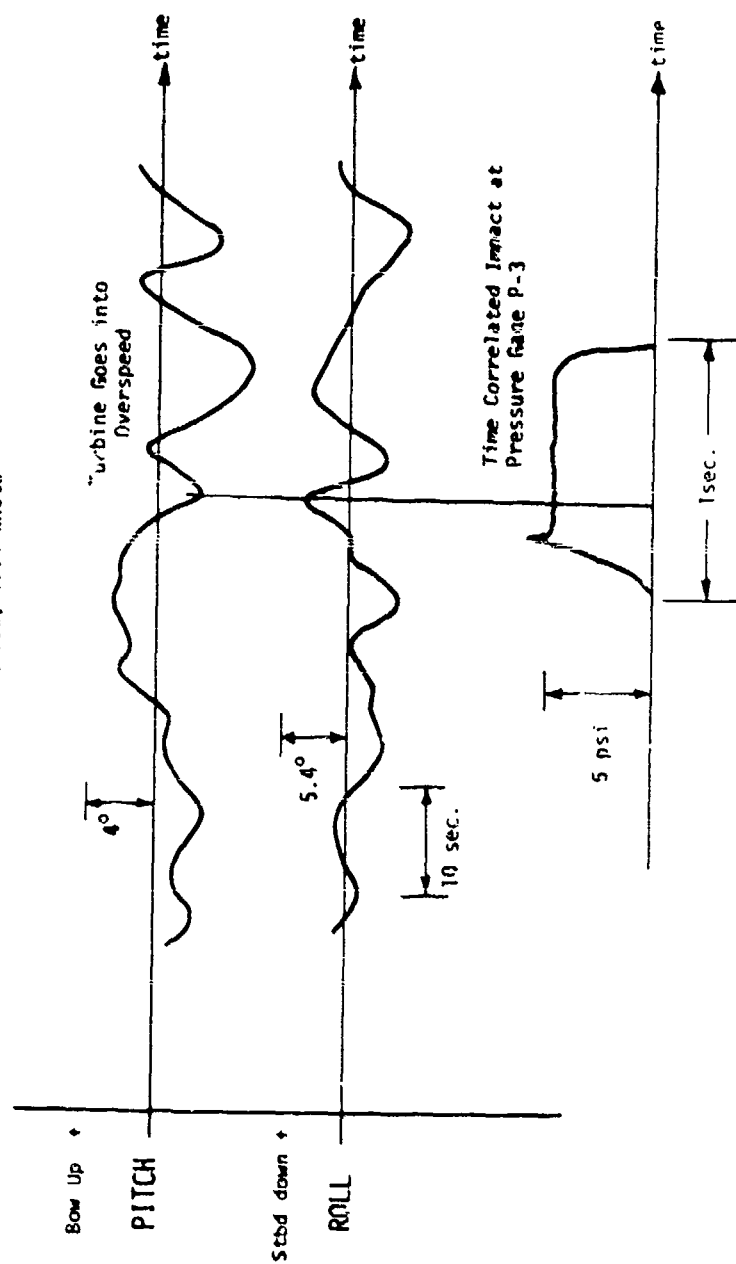


Figure 25A -- Sample Strip Chart Record of Pitch, Roll and Impact Pressure in Following Sea State 4



# SSP KAIMALINO

FOLLOWING SEA = 0° HEADING

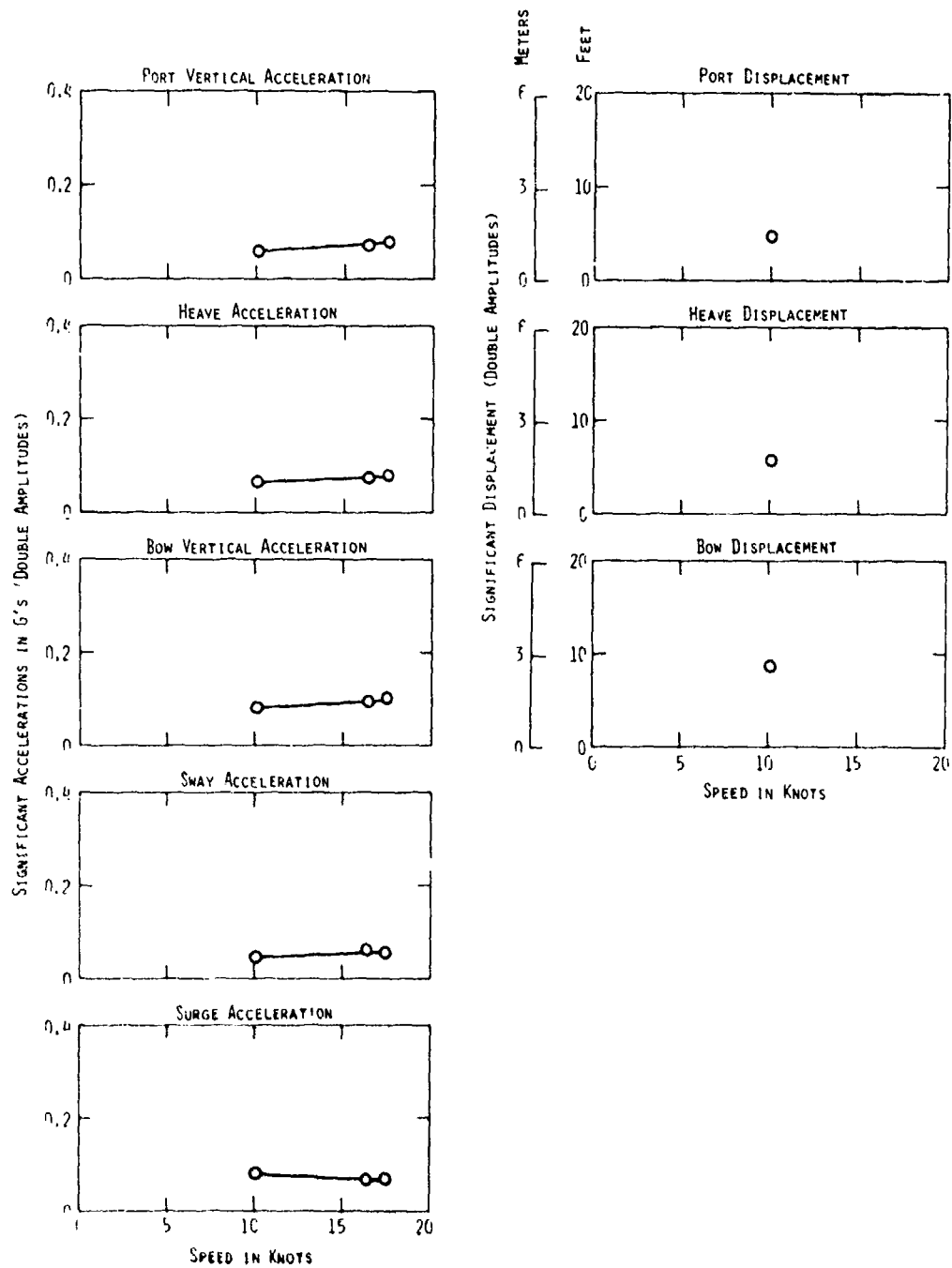


Figure 26 - SSP KAIMALINO Accelerations in Following Sea State 4

# SSP KAIMALINO

FOLLOWING SEA = 0° Heading

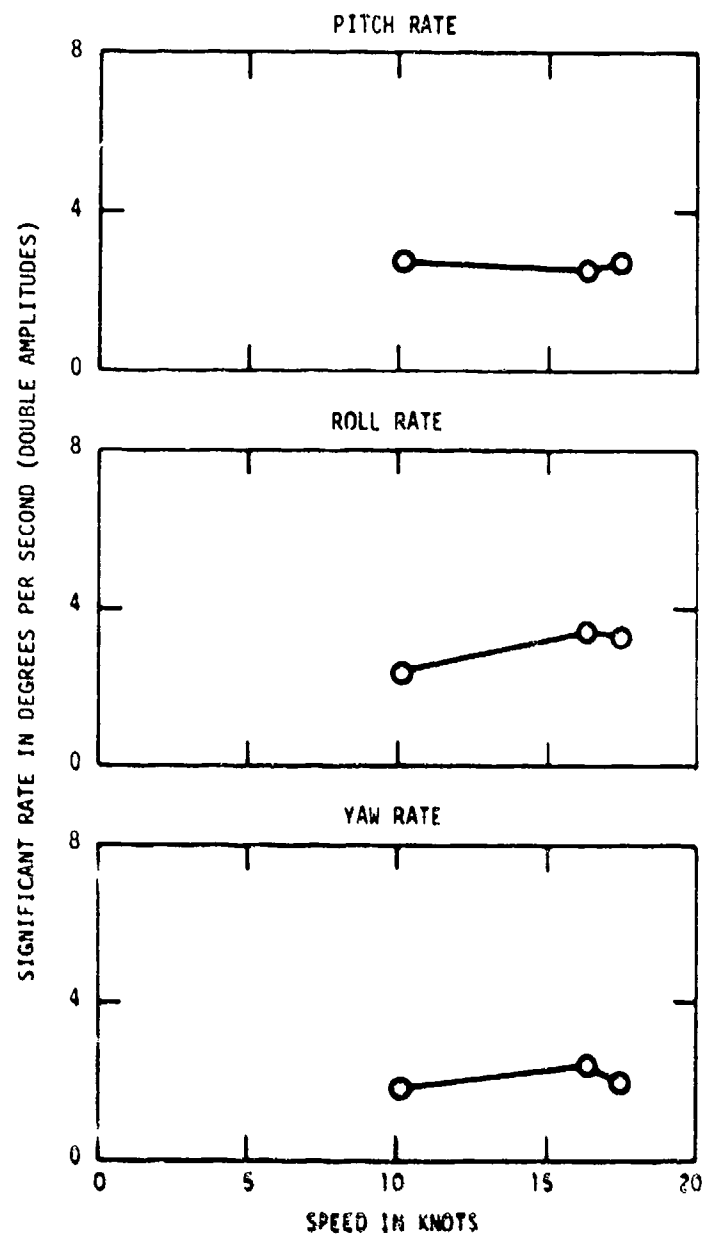


Figure 27 - SSP KAIMALINO Motion Rates in Following Sea State 4

# SSP KAIMALINO

FOLLOWING SEA = 0° HEADING

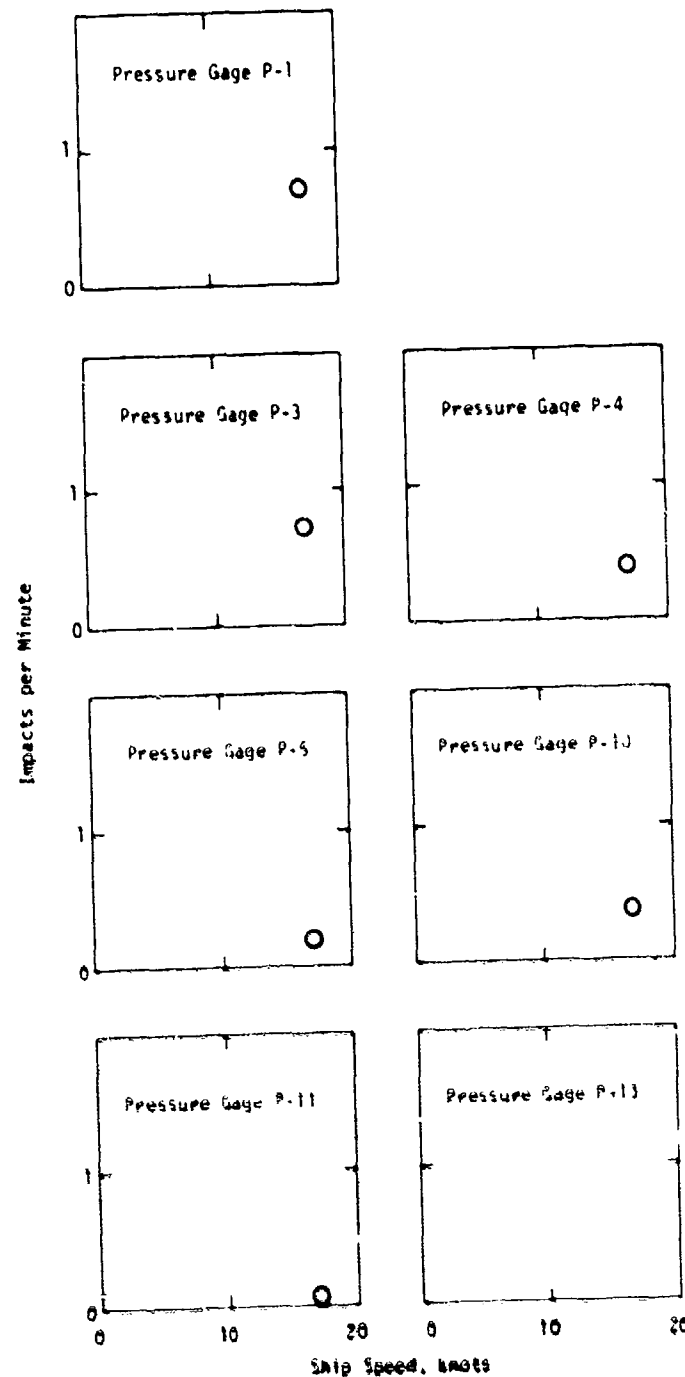


Figure 28 - SSP KAIMALINO Frequency of Impacting in Following Sea State 4

# SSP KAIMALINO

FOLLOWING SEA = 0° HEADING

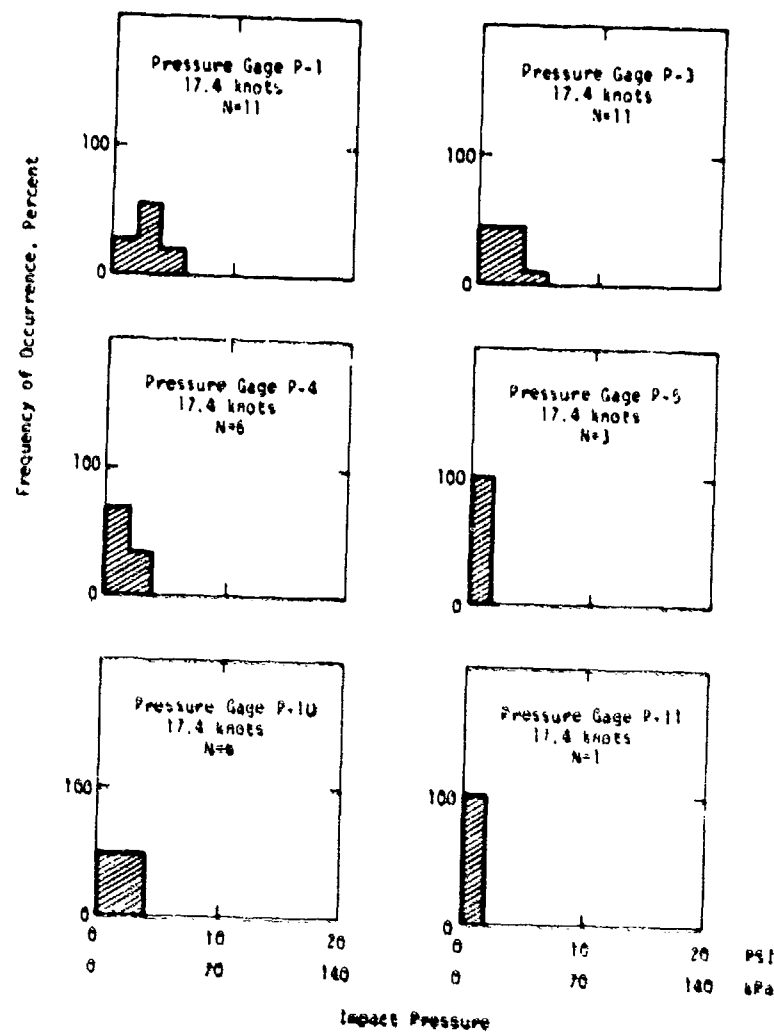


Figure 29 - SSP KAIMALINO Impact Pressure Histograms for Pressures Measured in Following Sea State 4

# SSP KAIMALINO

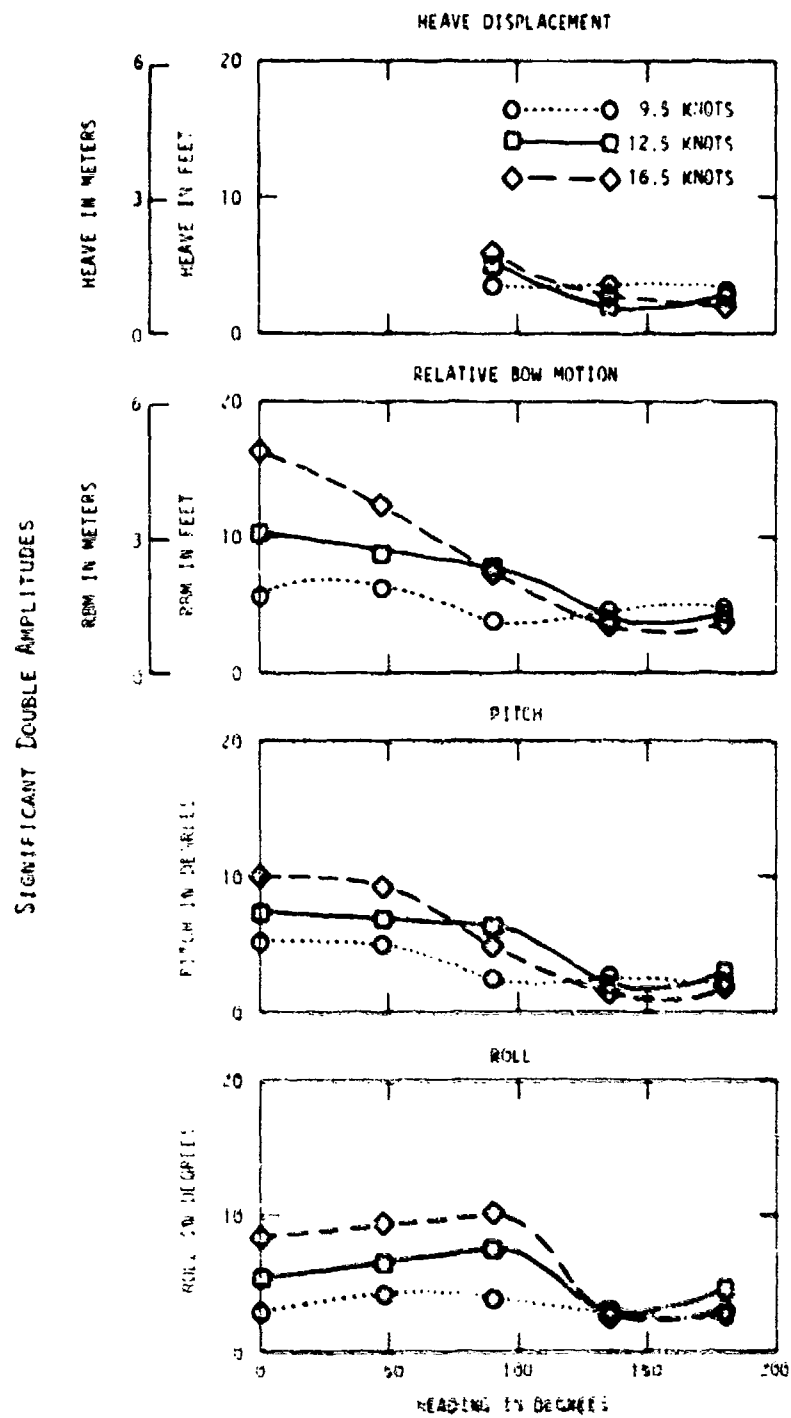


Figure 30 - SSP KAIMALINO Motions in Sea State 4 at Various Speeds and Headings

# SSP KAIMALINO

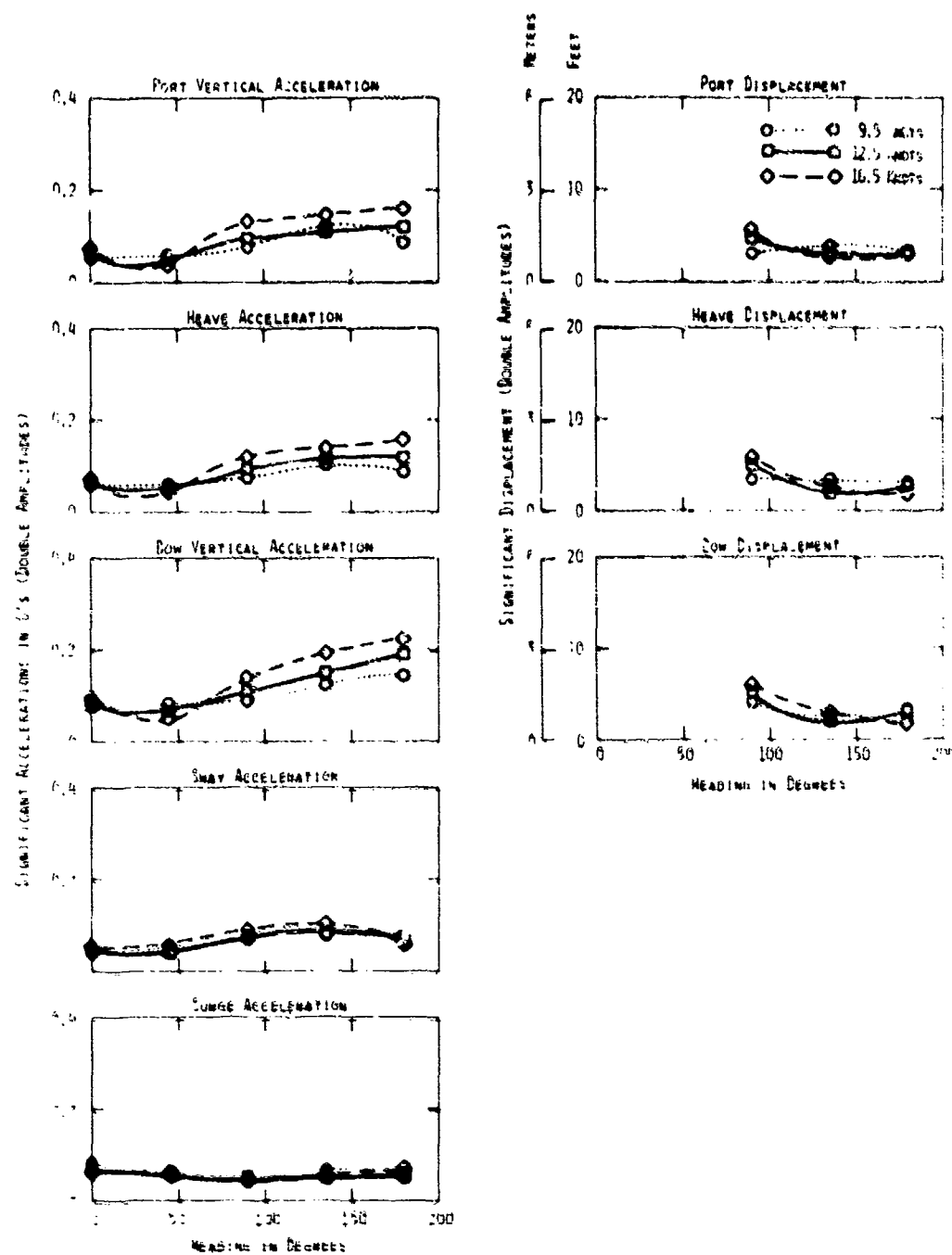


Figure 31 - SSP KAIMALINO Accelerations in Sea State 4 at Various Speeds and Headings

# SSP KAIMALINO

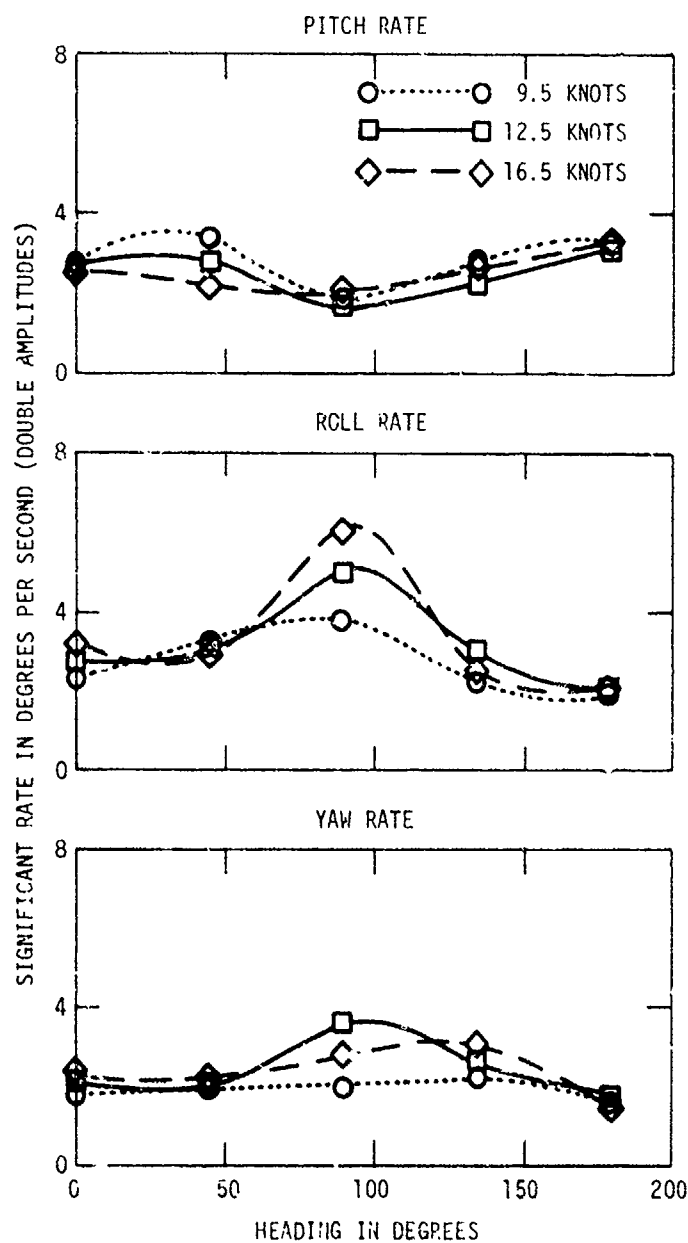


Figure 32 - SSP KAIMALINO Motion Rates in Sea State 4 at Various Speeds and Headings

# SSP KAIMALINO

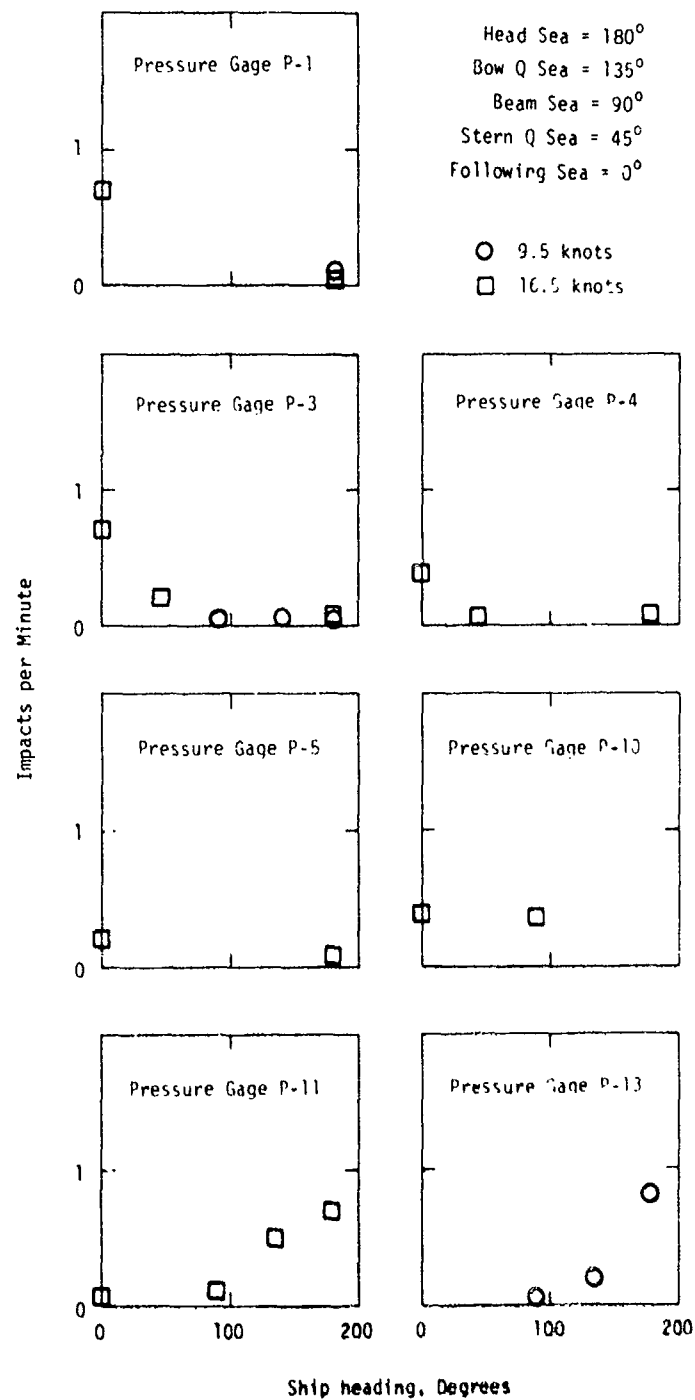


Figure 33 - SSP KAIMALINO Frequency of Impacting in Sea State 4 at Various Speeds and Headings



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